

EVALUATION OF STRATEGIES FOR THE MANAGEMENT OF REGIONAL BLOOD CENTRE

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CERTIFICATE

This is to certify that this work on 'EVALUATION OF STRATEGIES FOR THE MANAGEMENT OF REGIONAL BLOOD CENTRE', by Indu Shekhar Singh has been carried out under my supervision and has not been submitted elsewhere for the award of any degree.



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SYNOPSIS

The present work deals with the evaluation of strategies for the management of a Regional Blood Centre. The two strategies considered are referred as Single Cross Matching (SCM) and Double Cross Matching (DCM). In single cross matching only one unit (a bottle of blood) is reserved against each unit requested by the patient while in double cross matching an attempt is made to reserve two units in the name of one patient for each unit's reservation request by him. Actually only two units are reserved for two reservation requests by different patients, but the units reserved in their names are paired such that each paired unit is reserved in the name of both the patient and in the event of call for the unit by them older of the two units are issued first irrespective of their reservation. For each paired unit the patients are referred as primary and secondary patients. The unit for which reservation request is received from a patient is referred as primary patient and the other paired patient as secondary patient. The primary patient for a unit is the secondary patient of the other unit of doubly cross matched pair.

A simulation model was developed for the above stated strategies. The performances of the two strategies were studied considering various criteria viz., blood utilization efficiency, shortage and wastage reduction. Computer packages were developed

for the simulation model considering 1 day and 3 days of holding periods for reservation. Results for forty eight simulation runs were obtained and analyzed. The input data was generated within the desired limit of the parameters. In the case of double cross matching the effect of pair minimum age difference on the criteria was also studied.

A case study was developed based on the data obtained from Red Cross Unit, Poona and Sasson Govt. Hospital, Poona. Since the data was not complete for simulation analysis the other desired data were generated in a manner similar to generated data case. The results based on the case study for both the strategies were critically analyzed.

On the basis of generated data and case study, results indicated that in most of the cases the performance of double cross matching strategy is ^{slightly} superior to single cross matching in terms of lower shortage and higher percentage utilization efficiency. The case study indicated ^{slightly} better performance of single cross matching strategy in terms of blood wastage.

Based on the study, the adoption of double cross matching strategy has been recommended for Regional Blood Centre dealing with large number of units.

CHAPTER 1

INTRODUCTION

The industrial revolution lead the people to realise the importance of technology and latter the Theory of Scientific Management by Taylor added significant effect not only on the industrial scene but also on the social and human welfare fields, because ultimately a significant interaction exists between them. Although the Taylor theory was confined to cost reduction or profit maximization but its effect was so great that it changed the basic outlook towards any venture whether industrial or social.

The present work is mainly concerned with human welfare problem. It deals with policy formulation for regional blood centres with a view to reduce the blood wastage and shortages. Unlike other commodities the management of blood inventory and its distribution has to be considered in a different way due to its ethical and valuable significance.

1.1 CHARACTERISTICS OF BLOOD FOR TRANSFUSION:

Some of the important characteristics of blood inventory are:

(1) Human blood is the most vital commodity for human beings. It saves the very existence of the human beings in emergent situations.

2. Blood is a perishable commodity. Its widely accepted life for transfusion purposes is only 21 days.

3. The blood before transfusion is to be properly matched as only similar group of blood can be transfused to a particular human being.

1.2 EXISTING PRACTICES AND PROBLEMS.

There are numerous practices being followed all over the world with regard to the blood inventory and its distribution. In India, the following practices are being most commonly used by the blood centres.

i) The blood is procured from voluntary donors and relatives of needy patients.

ii) The blood is stored in bottles of 450 ml. capacity in cool and dark place (usually at 4°C).

iii) Once the blood is procured it is checked for its group (A, B, O, AB) and Rh-factor (positive or negative) and these information are labelled on the bottle.

iv) On getting a request from patients, the blood is issued from the stock, if matching blood is available, otherwise refused.

v) The system of reservation and call with holding periods is not used generally, which leads to uncertainty for availability of blood for transfusion purposes.

vi) Once the blood is issued, it is not returned to the blood centre in any case even if it is not used and still has some useful life for transfusion, which otherwise could have been issued to other patients.

1.3 MOTIVATION AND DOMAIN OF PRESENT WORK:

During the past one decade number of publications have appeared in the literature on blood inventory management and distribution. In the literature two distinct approaches have been suggested. These referred as Single Cross Matching (SCM) and Double Cross Matching (DCM) have been suggested. However no serious efforts seem to have been made to evaluate the relative performance of these two approaches.

In this thesis, therefore, an attempt is made to study the relative performances of single and double cross matching strategies for regional blood centres. The various criteria considered for evaluation include measures like shortage, wastage and utilization of the procured blood. The complete details of single cross matching and double cross matching strategies have been presented in Chapter 3.

The mathematical modelling of the above mentioned two strategies is very complex and as such simulation approach has been developed for the evaluation of the two strategies. The relevant information have been generated using uniform random distributions within suitable limits (details presented in Chapter 3) keeping in view the computer memory constraints. The actual data has also been procured from Red Cross unit, Poona and Sasson Govt. Hospital, Poona. The data collected could not give all the needed information for the simulation

model. All the collected information was utilized and other necessary information has been generated suitably.

1.4 ORGANIZATION OF THESIS:

In Chapter 2, the literature on the blood inventory covering its various aspects, viz., management control, issuing policies, computerized information system and operational policies, have been briefly reviewed.

In Chapter 3, a formal statement of the problem is presented and the single cross matching and double cross matching strategies have been described. Further, the various assumptions underlying the development of simulation model and the detailed description of the subsystems of the model is given.

In Chapter 4, the simulation results have been tabulated for the generated data as well as the case study. Results have been discussed and analyzed to evolve suitable strategy for the management of regional blood centres. Further a few suggestions have been made for the future work in this area.

CHAPTER 2

LITERATURE REVIEW

The first mathematical model for scientific inventory management was developed by F.W. Harris in 1915 and since then large number of contributions have appeared in the literature on inventory management. Most of these papers deal with industrial products and relatively very little has been published in the area of Blood Inventory Management. In this chapter, we shall review some of the important contributions in this area.

Chazan and Gal⁽²⁾ have analyzed the outdating rate and age distribution of blood. They assumed that after each period's demand the inventory is replenished with fresh unit upto a constant level and the age distribution has been treated as a Finite Markov Chain. They obtained the lower and upper bounds for the expected outdating in the case of general demand distribution. The authors have also pointed out that better and easily computable bounds can be found for the Poisson demand case.

Mole⁽¹¹⁾ in his paper pointed out that policy decision should be one which balances the conflicting stock requirements of maintaining a high availability and also low outdating rates. Markovian structure was used for the development of the mathematical model and effects of the key variables were studied and found to be interrelated. For the sake of simplicity, Mole has carried out the analysis on weekly basis rather than the usual daily basis.

Brodheim et al.⁽¹⁾ have also modelled the distribution policies for scheduled deliverance of perishable products subject to variable demand using Markov Chain with a manageable number of states. Using stationary distribution measures like probability of shortage, the average age of inventory and the average number of discarded blood bottles per time period were obtained. Easily computable bounds on these measures were developed which indicated as to how the measures mentioned above behave as a function of demand and inventory policy parameters.

Pegels and Jelmert⁽¹²⁾ have studied the various human blood issuing policies on the basis of theoretical model using mainly the theory of absorbing Markov chains. They observed that the issuing policies affect the average inventory level, which in turn determine the shortage probabilities and the average age of the blood at the time it is being transfused.

Modified LIFO (which is issue fresher blood with higher probability than older blood) and modified FIFO along with LIFO and FIFO policies were considered for complete evaluation of the policies, so that a choice can be made on the basis of evaluation.

Pierskalla and Roach⁽¹⁾ have considered the various issuing policies under several possible objective functions. The blood inventory is grouped into categories according to shelf age. Whenever demand occurs for a particular category, the demand is satisfied either from the inventory units in that category or any younger category. It is shown that for most of the objective functions considered by the authors, the optimal policy is to issue the oldest unit first (FIFO) which will satisfy the demand.

Cumming et al.⁽⁵⁾ have suggested a planning model for Regional Blood Suppliers in alleviating seasonal imbalances between supply and demand of blood. Various performance measures for a blood supply region were tested on a Markovian population model through graphs for a planning period varying between 3 - 12 months. The planning model iteratively develops improved collection plans. The authors claim that the iterative planning model is sufficiently accurate and highly effective for its cost. The model has been implemented by two regional blood suppliers using remote computer control. Basically this paper deals with the development of blood procurement policy.

Frankfurter et al.⁽⁷⁾ have suggested a methodology for the design, development, implementation and operation of short term blood inventory level forecast system, which helps the blood centre management in taking corrective action to either reduce or increase the blood collections.

Leibman⁽¹⁰⁾ has developed a computer oriented Management Information System for blood inventory. The information system generates routine management reports on outdated blood, blood two days from outdating, available supplies and blood requirements. The author claims that the use of his inventory information system resulted in reduced average amount of blood assigned but not subsequently used.

Jennings⁽⁹⁾ points out the inventory control problem of blood bank is extremely complex innature and involves four main functions of procurement, store, process and supply. The complexity of the problem has been attributed to the following four reasons.

- (i) Both supply and procurement are random.
- (ii) Approximately 50 percent of the blood demanded, cross-matched and held for a particular patient are eventually found not to be required for that patient.
- (iii) Blood is a perishable item with a legal life of 21 days.
- (iv) Each blood centre interacts typically with a number of hospitals.

The author has developed models for the management of blood inventory on regional basis. Further alternative inventory policies have been analysed.

Dumas and Rabinowitz⁽⁶⁾ have given new operational policies for reducing wastage (due to blood exceeding its transfusable age limit) without adversely affecting shortages (stock outs). They have further suggested the policy of DOUBLE CROSS MATCHING. This policy tests the same unit of blood for compatibility with two potential recipients (so that it is available for use by either) and also insures that blood is available for both. Further they have suggested another policy of using Rh-negative blood for Rh-positive patients under certain blood age conditions when medically feasible. The simultaneous use of both policies were also investigated. The performance of these policies were measured by wastage cost effectiveness over a range of demand levels. The operational procedures for using these policies have also been discussed.

Pegels and Wallace⁽¹²⁾ have suggested a computerized instant access information system. The system considers 21 days life of human blood for useful transfusion. Important components of the information system are:

(1) an inventory system which keeps track of each individual unit of blood with its age and flags when it is due to outdate.

(ii) a short term inventory level forecasting system which forecasts the system inventory level on a daily basis for the next two weeks on the basis of current inventory, forecasted demand and forecasted supply.

(iii) an allocation model which allocates the blood in such a way that shortages and transportation cost are minimized. Further operating results have been given for the system.

Frankfurter et al.⁽⁸⁾ have developed a computerized blood inventory system for a set of affiliated hospitals. Daily information regarding blood bottle code number, blood type, expiry date, date of procurement by the hospital, number of bottles in stocks are daily recorded and updated on the computer. Affiliated hospitals contact the computer system directly to acquire their inventory reports. These reports include variety of summary statistics to assist the hospitals in better planning and control of blood.

Pegels et al.⁽¹⁴⁾ have evolved a planning system which utilizes conversational computer facilities to assist the manager of a regional or community wide blood agency in scheduling blood mobiles and fixed facility collections from one to eighteen months in advance.

Further the above authors along with Shubsda have examined the following four policies for their effect on shortage, efficiency etc., using a computer-based planning system.

- (i) Use of frozen red cells: technological alternative.
- (ii) Extension of useful life of blood: legal alternative.
- (iii) Improved collection planning: planning alternative.
- (iv) Improved inventory management: management alternative.

The comparative performance of each policy with respect to the principal objectives have been discussed in detail in reference⁽¹⁵⁾.

Cohen and Pierskalla⁽³⁾ have developed a system model using the techniques of management science and mathematical inventory theory to identify policy areas and formulate management objectives. Two simulation models have been used in analysis with actual data from different source. The results presented examine the interactions and savings associated with the use of optimal ordering, cross match and issuing policies. Further the authors have examined the question of centralized versus decentralized control.

Cohen et al.⁽⁴⁾ have applied O.R. techniques to blood service complex. Mathematical response functions have been developed from the analysis of the data in each segment. The various segments considered include demand, forecasting, cross match and recycle control at each level of hierarchy in a regional system. They have further stated that these hierarchical models can reduce outdateding, size of inventories and shortages.

Pegels and Seagle⁽¹⁶⁾ have considered the extended life of blood for useful transfusion and observed that it will significantly reduce the outdateding and maintaining higher inventory levels. The study is based on the use of probabilistic model. An obvious adverse effect of the above strategy is the transfusion of older blood which may not be good from medical reasons.

The above survey reveal that very little work has been done on cross matching strategy for the management control of blood inventory. Eventhough some work has been reported for DOUBLE CROSS MATCHING, in this thesis an attempt is made to further extend the concepts of double cross matching and compare it with single cross matching.

CHAPTER 3

PROBLEM FORMULATION AND SOLUTION METHODOLOGY

3.1 PROBLEM STATEMENT:

Blood is collected from human body and stocked suitably so that it can be used for human being for transfusion purpose, when the need occurs. As only the matching blood can be transfused and the demand for the blood should be satisfied to the maximum possible extent, sufficient stock with suitable collection and distribution policy has to be established with the following main objectives.

- (i) Shortage should be at the least possible level, as it has direct impact on the very existence of human being.
- (ii) Wastage also should be at the minimum possible level for efficient utilization of the procured blood, thereby leading to easy procurement from voluntary donors.

Further the cost associated with the development of any suggested strategy for the fulfilment of above objectives should be minimum or atleast comparable with the gains in the system efficiency.

3.2 SYSTEM DESCRIPTION.

The procurement of blood at blood centre is mainly through the voluntary donors. In most of the situations, persons go to blood bank and donate their blood mainly on ethical considerations. However, sometimes they might be donating the blood for getting a certificate from the bank to this effect, so that on the basis of that certificate he can get blood any time in future for himself or his nearby relatives in case of emergent need. Blood centre accepts their blood after some primary checks and stores them in bottles of certain volume. Then the group of the blood is determined after test and the bottle is labelled with its group number, date of procurement and bottle number.

Further on getting a request from hospital for blood bottle along with the sample of the blood, the sample is matched with the blood bottle in unassigned stock after the determination of its group. Hence on availability of properly matched blood the request for reservation is satisfied, otherwise shortage is declared. In both the situations hospital is informed accordingly.

Blood centre identifies blood bottles in three separate stacks and accordingly the stocks are known as (i) Unassigned stock, (ii) Reserved or assigned stock, (iii) Outdated stock.

Unassigned stock consists of initial unreserved units, freshly procured units, unused returned units from hospitals (within reuse age limit) and cancelled units from reserved stock (within reuse age limit) as shown in Fig. 3.1(a).

Reserved stock consists of units reserved from unassigned stock on getting request for the same from hospitals and availability of the units in unassigned stock as shown in Fig. 3.1(b).

Outdated stock consists of units returned from hospitals exceeding the reuse age limit, cancelled units from reserved stock exceeding the reuse age limit and the units exceeding the reuse age limit from unassigned and assigned stock as shown in Fig. 3.1(c).

3.3 BLOOD MATCHING STRATEGIES.

The aim of the present work is to evolve and evaluate alternate strategies for the management of a regional blood centre such that the maximum number of patients are satisfied and the overall wastage of blood is minimum. The problem described in Section 3.2 has been attacked by the following two approaches.

- (1) Single Cross Matching : (SCM)
- (11) Double Cross Matching : (DCM)

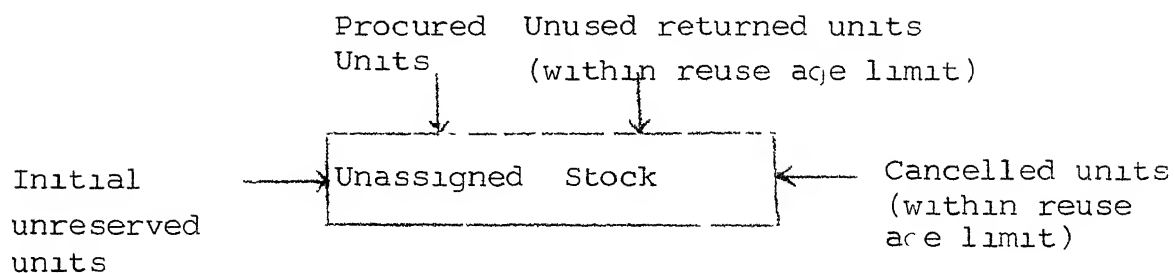


Fig. 3.1(a)

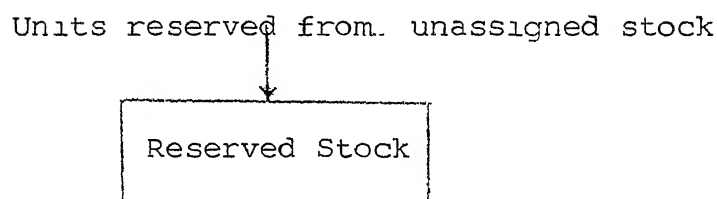


Fig. 3.1(b)

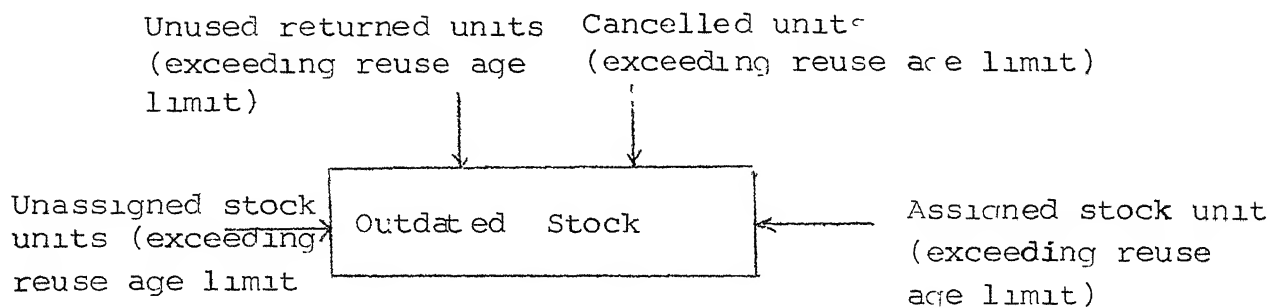


Fig. 3.1(c)

3.3.1 Single Cross Matching:

In this policy, on getting a request from doctor or hospital, the blood bank or blood centre reserves the bottle after proper match in the name of the patient for which the request was received, if the bottle is available in the unassigned stock by following the FIFO policy. If the same is not available shortage is declared. In both the situations the doctor or the hospital is informed accordingly.

The reserved units are kept for individual patients for certain period known as the holding period for reservation. Within this period the reserved blood can be called by the doctor or hospital for transfusion. If it is not called within this period, the reservation is cancelled and these bottle/s of blood join the unassigned stock. The blood centre will maintain three separate stocks viz., assigned stock, unassigned stock and outdated stock. Further, the called blood can be kept by the hospital for certain period known as 'holding period for call', so that it can be transfused in actual need within that period. If the called blood is not used, then at the end of holding period for call it is returned to the blood centre.

3.3.2 Double Cross Matching:

In this policy, for any given two patients (pair of patients) each requiring a unit of blood of the same type, two

matched units of blood are reserved in a paired fashion. Each of the two reserved paired units is made available to either of the patients. Corresponding to each blood unit patients are assigned in the same manner as in single cross matching. The pair of blood bottles to be formed is identified considering the blood age difference of the assigned bottles (a decision variable). The use of single cross matching identifies the primary patient for the paired blood units. For each blood unit in the pair, the second patient in the pair gets the status of secondary patient. The reservation scheme in this policy may be represented as shown below:

Bottle Number	Primary Patient	Secondary Patient
1	A	B
.		
.		
.		
n	B	A

It needs to be noted that the reservation of only single unit of blood for the two patients is not proper, as there is a reasonable chance that both patients will need blood. Hence a second unit is cross matched against both patients and reserved. Thus in the double cross matching neither patient is in danger of being denied a unit of blood in the event of calls for blood by both of them.

In this policy, in the event of cancellation, at the end of holding period for reservation with respect to primary patient, the same unit of blood is now made singly reserved in the name of secondary patient, but now as primary patient and the unit of blood reserved for secondary patient earlier as primary patient is now made the member of unassigned stock as shown below:

Bottle Number	Primary Patient	Secondary Patient
1	B	A
.		
.		
.		
n	X	X

where X stands for possible entry that can be made after cancellation

Further in this policy, if the call is made by any one of the paired patients, the older unit of blood is issued first even if the call comes from the secondary patient. However if the call is made by both of them, both the paired units are issued.

Double cross matching does not increase the overall probability of use but may be used to shift some probability of use between units. If priority of use is based on age, and if one unit is relatively close to its expiration date and the other is relatively fresh, the above policy may reduce wastage by increasing the probability of using the older unit before expiration date - while increasing the probability that the younger unit will grow little older.

This policy puts the same number of units on reserve as the conventional reservation system but greatly increases the number of cross matches performed, i.e., increases the work load considerably.

The present work is directed towards studying the relative performances of the above stated two strategies in regard to the objectives of minimization of blood wastage as well as its shortage. Further an attempt is made to select the best set of decision variables (stated below) for both the strategies.

(i) Holding period for reservation of one day and three days have been investigated in the present work.

(ii) The minimum age difference between the older and fresher units of blood forming the pair in case of double cross matching. Age difference of 3 to 14 days between older and fresher units of blood have been considered.

The problem as described earlier is too complex to be considered mathematically, therefore a simulation approach is adopted for the same.

The development of the simulation model is based on certain assumptions. Some of the important assumptions involved there in are stated below.

3.4 ASSUMPTIONS:

(i) The useful life period of human blood for transfusion purposes is assumed to be 21 days, which is legally and widely accepted all over the world.

(ii) The demand and supply of blood will be in terms of units of bottles (usually 450 ml in a bottle) even if the demand is in part, it should be treated as the next higher number.

(iii) Only the reserved units can be called.

(iv) The holding period for a called unit by the hospital is assumed to be 3 days. This holding period is referred as 'holding period for call'.

(v) The reservations are made on the FIFO basis.

(vi) At the blood centre, the procured blood bottles are assigned Permanent Bottle Number (PBN) serially in the order of their age.

(vii) The procurement of blood on any day is of fresh blood only and all fresh blood entering the blood centre is treated as blood which is one day old.

(viii) In this thesis the term 'unit' will be used to signify a bottle of blood or any part thereof.

(ix) The initial stock comprises of units which are either 17 days old or below in age.

(x) Keeping in view the computer memory limitation the limit for different parameters, such as, number of units in the initial stock, number of units demanded on a day, number of units called, number of units returned and number of units cancelled has been assumed to be 50. On the basis of this limit other related parameters, viz., maximum number of patients requesting reservation and the maximum number of units requested by each patient has been assumed to be 13 and 4 respectively. Procurement limit is also assumed as 50.

(xi) The parameters mentioned under assumption (x) are assumed to be generated randomly from uniform distributions.

(xii) All the analysis are with respect to any single type of blood.

3.5 SIMULATION MODEL DEVELOPMENT:

A simulation model which involves the consideration of various subsystems described below has been developed. A computer package for the simulation model has been developed for the IBM 7044 - 1401 system.

3.5.1 Model Description:

The model includes the following:

(i) Initialization: This deals with the initialization of variables and takes care of previous stock entry, if any.

(ii) Procurement: This subsystem deals with the daily collection of blood bottles.

(iii) Return of Unused Units: This subsystem enters back the information regarding the bottles of blood which were called earlier but could not be used and as such are returned.

(iv) Call of Units This subsystem deals with the call of blood bottles which were reserved earlier and is within the holding period.

(v) Cancellation of Reserved Units: This subsystem cancels the reservations made earlier after the expiration of holding period for reservation.

(vi) Reservations: This subsystem deals with reservation of units on the receipt of reservation request from hospitals or doctor depending upon the unassigned stock in the centre, otherwise shortage is declared. Reservations are made either using single cross matching or double cross matching. Further the age of each collected unit is updated.

(vii) Statistics This subsystem deals with the updating of the stock, calculation and printing of desired outputs.

For better comprehension of the blood centre problem, it would be worthwhile to state day-wise, as to what events

would take place in the blood centre. Fore- in discussion is based on 3 days holding period for both reservation and call.

On the first day there will be first procurement and first reservation. Besides the first procurement the unassigned stock will consist of the previous stock on ac.

On the second day there will be second procurement, first call and second re-ervation.

On the third day, there will be third procurement, second call and third reservation.

On the fourth day, there will be fourth procurement, third call, first cancellation and fourth reservation.

On the fifth day, there will be fifth procurement, first return, fourth call, second cancellation and fifth reservation.

Likewise from sixth day all important events take place on similar lines stated above for five days. It should be noted that the reservations of blood are done using either single cross matching or double cross matching.

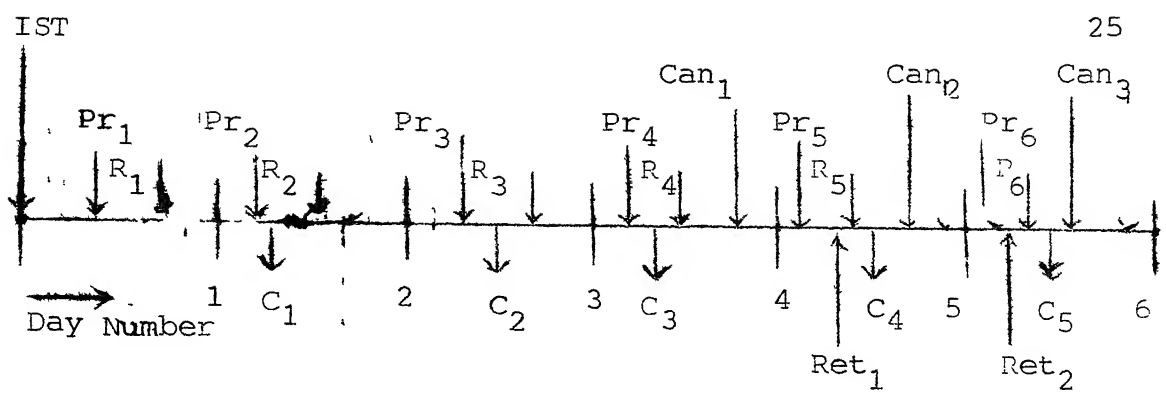


Fig. 3.2

In Fig. 3.2 IST represents the initialization of the systems while Pr, R, and C represent procurement of units, reservation of units using a strategy, and call of units reserved earlier respectively. Further, Can and Ret represent the cancellation of reserved units which could not be called and return of called but unused units respectively. The subscripts (1,2,..., 6) indicates the sequence number of occurrence of different events after the start of the simulation. Fig. 3.3 depicts unit and information flow in the model.

From the diagram shown in Fig. 3.4, it is evident that at the start of the simulation, all important parameters are initialized and the day number is set equal to 1. The unassigned stock file is updated by adding the day's procurement to the previous unassigned stock if any. Depending upon the actual conditions for occurrence of different events (explained earlier in Fig. 3.2) following events take place in order.

- (i) Return of unused but called units by hospitals.
- (ii) Call of units reserved previously.

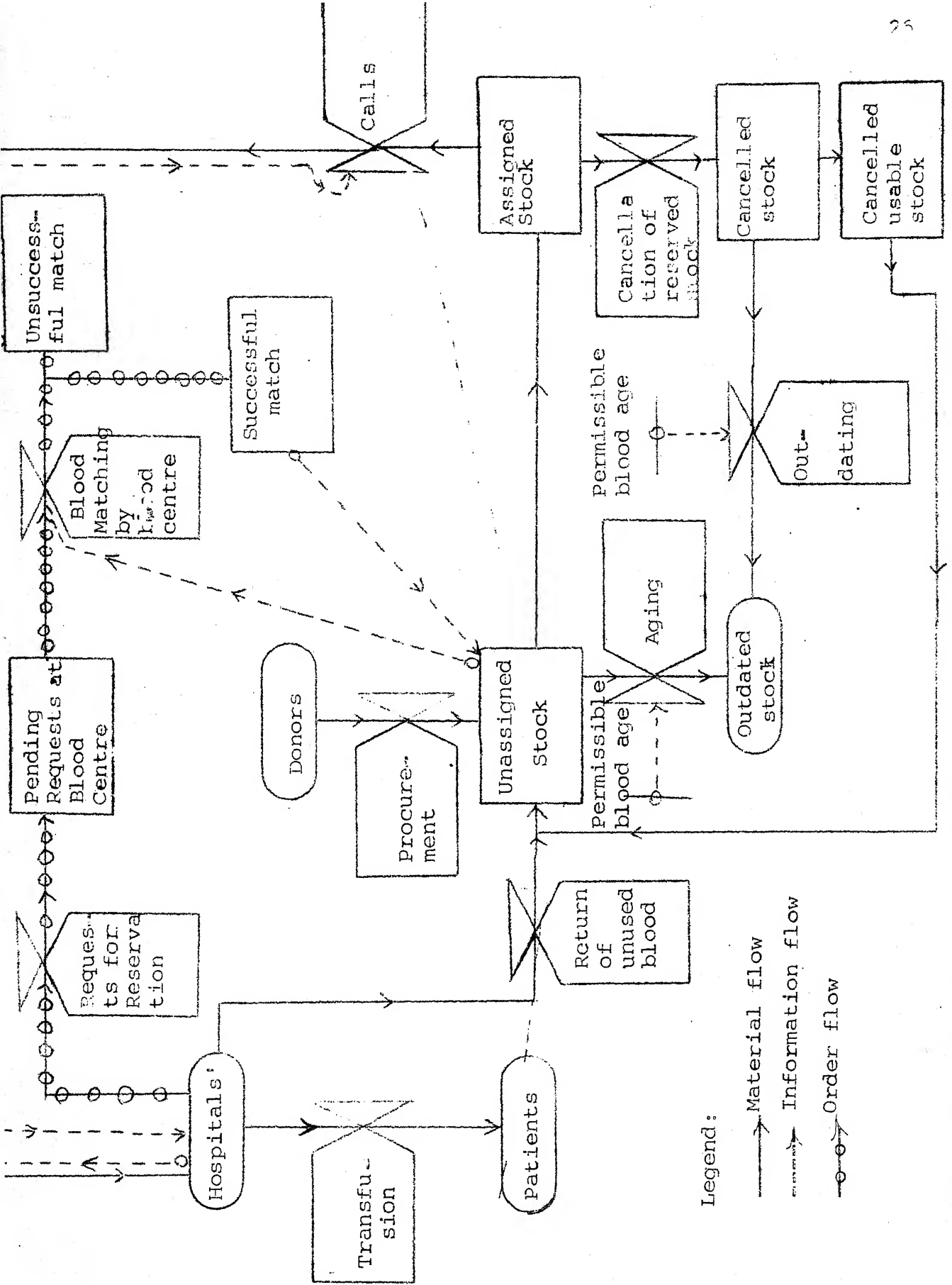
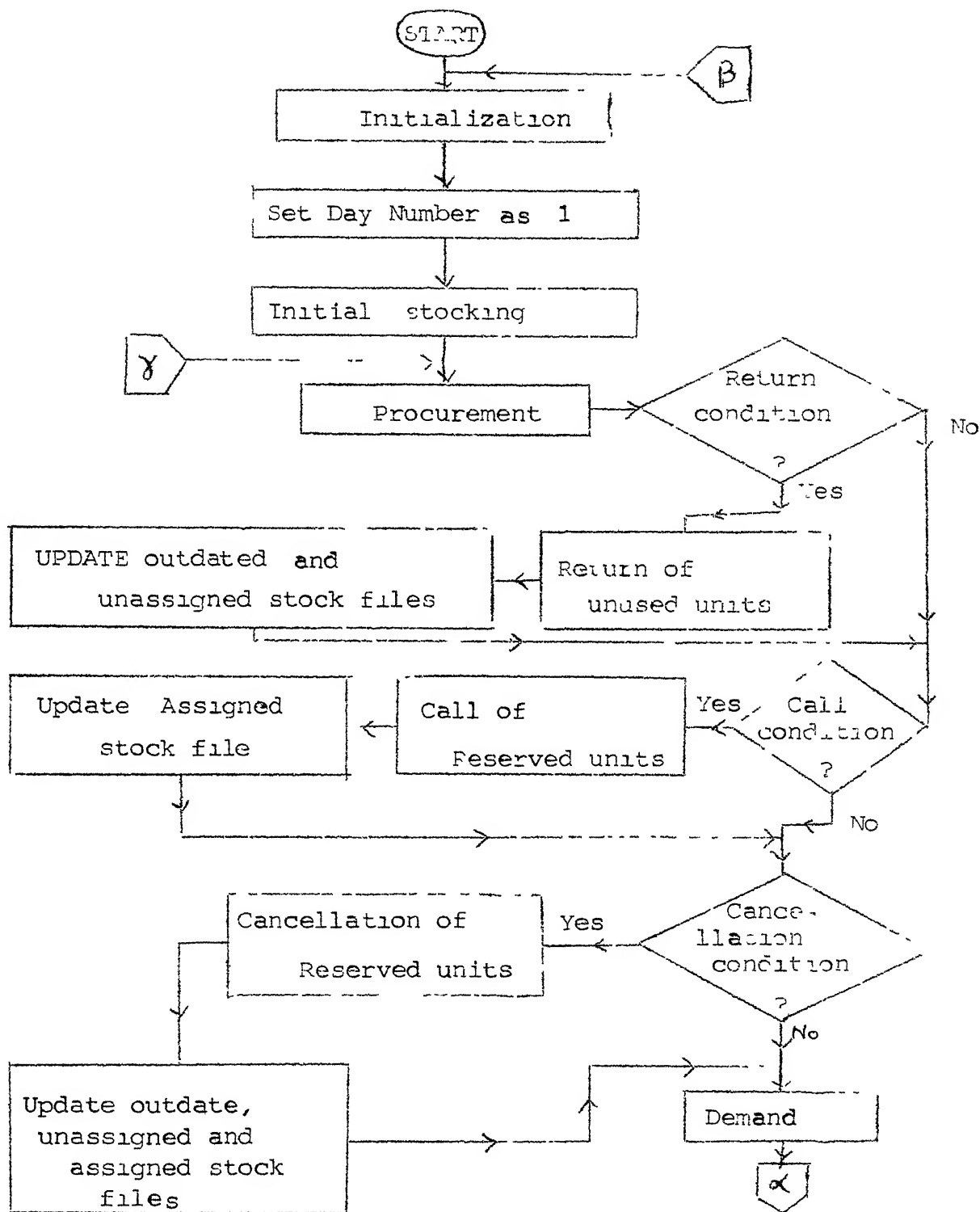


Fig. 3.3: Material and Information Flow Diagram for the Model



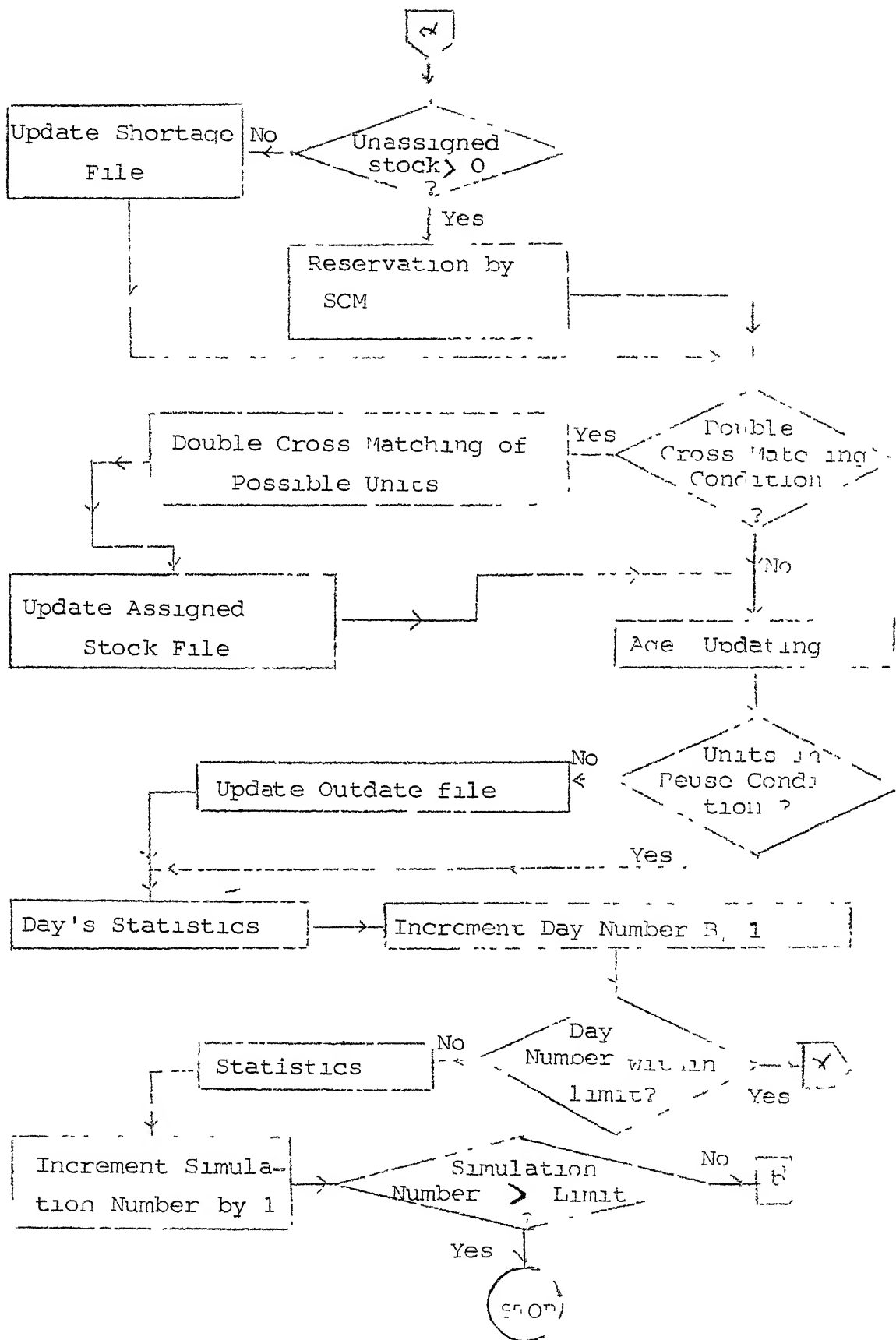


Fig. 3.4: Flow Diagram of Simulation Model.

(iii) Cancellation of units reserved but not called by the hospitals at the end of holding period for reservation.

(iv) Reservation of units on the basis of demand occurring on the day.

(v) Age updating.

(vi) Statistics.

After this, the day number is increased by one and the same procedure from procurement is repeated till the limit set for next simulation is reached. Then the final results are printed and depending upon the requirement, the analysis is carried out again by initializing the whole system for next simulation, otherwise the simulation runs terminate.

3.5.2 Nomenclature:

The following are some of the important notations that have been used for the development of the computer package as well as for describing the various aspects of the subsystems with respect to a simulation run.

3.5.2.1 Variables:

DN	Day Number of the simulation run.
PBN	Permanent Bottle sequence Number labelled by the centre.
COLLECT	Collection of fresh units on a day by the centre.

TBD	Total number of Bottles Demanded from the centre.
TNP	Total Number of Patients for whom reservation requests came.
TSORTG	Total number of Shortages of units at the centre.
TCALL	Total number of units Called from the centre.
TUNCAL	Total number of Units Not Called from the centre.
TCNUSE	Total number of units Called but Not Used by the hospitals.
TBDAP	Total number of Bottle Doubly Assigned Pairs made at the centre.
TCLECT	Total number of unit Collected by the centre.
TBSA	Total number of Bottles Singly Assigned by the centre.
TPSA	Total number of Patients Singly Assigned by the centre.
TUNCG ^W	Total number of Units Not Called and are Going Waste.
TCNUC ^W	Total number of Called units Not Used and are Going Waste.
TAG ^W	Total number of units Actually Going Waste due to aging only.

UNASND total number of Unassigned Units available
at the centre.

ASIND minimum number of units Assigned for requests
met before.

ODATE total number of units Outdated.

NOPR Number of Patients Requesting for reservations
on a day.

NOBC Number of Bottles Called on a day by the
hospitals.

NOBR Number of Bottles Returned on a day by the
hospitals.

3.5.2.2 Matrices:

The various matrices used for the development of the model are.

1. Match Matrix (MM): Relevant information for each unit collected at the blood centre such as identification number (a sequence number assigned to the blood unit at the centre after procurement), age, primary patient number after reservation, secondary patient number after double cross match pair formation and status are stored in a matrix known as Match Matrix (MM). The status of each unit is assigned values -1, -2, 1, 2, 3, 0 to represent the same. -1 indicates that the unit is below its reuse age limit and has not been reserved by any matching strategy, whereas -2 indicates that the unit was reserved

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earlier and as its age is below reuse age limit after possible return or cancellation of reservation of the unit, it can be reserved again. The unit is assigned value 1,2,3,0 to represent its status respectively depending upon whether the unit has been singly reserved (i.e., reserved for only one patient), doubly reserved (i.e., reserved for two patients), has been called by the hospitals or has become outdated.

2. Assigned Matrix (ASINED): For each patient, the permanent patient number (i.e., a sequence number assigned to the patient after the start of a simulation run), its first reserved unit number and the second reserved unit number (in case of successful double cross match) are stored in a matrix known as (ASINED) matrix.

3. Demand Matrix (DM): The information relevant with respect to day's reservation requests such as sequence number of unit demanded, sequence number of the patient on that day, permanent unit number of satisfied demand, permanent patient number and the status of request are stored in the matrix known as Demand Matrix (DM). With respect to a reservation request, the status in Demand Matrix is assigned values 1 or 0 for acceptance of request for reservation and shortage respectively.

3.5.2.3 Arrays:

The various arrays used for the development of the model are:

1. PROCUR This array (PROCUR) stores number of units procured of different age on a day.
2. IST This array (IST) stores number of units of different age of initial stock.
3. INTAKE This array (INTAKE) stores number of units collected on different day number.
4. DEMAND This array (DEMAND) stores number of units demanded on different day number.
5. NUCALD This array (NUCALD) stores number of units called on different day number.
6. CBNA This array (CBNA) stores unit numbers which are called and related informations on a day having day number equal to integer multiple of 3 plus one i.e. for $DN = 1, 4, 7, \dots$
7. CBNB This array (CBNB) stores unit numbers which are called and related informations on a day having day number equal to integer multiple of 3 plus two, i.e., for $DN = 2, 5, 8, \dots$
8. CBNC This array (CBNC) stores unit numbers which were called and related informations on a day, having day number equal to integer multiple of 3, i.e., for $DN = 3, 6, 9, \dots$

9. RETBNA This array (RETBNA) stores the unit numbers returned from hospitals and cancelled from reserved stock which can again be assigned alongwith related informations on a day.
10. RDCMBN This array (RDCMBN) stores the unit numbers to be considered for double cross matching and related information on a day.
11. CBARAY This array (CBARAY) contains the unit numbers reserved within three days and yet to be called by the hospitals.
12. RBARAY This array (RBARAY) contains the unit numbers reserved on the last three days by the centre.

The related informations in context with the above description are the day number, the number of units in the particular array and some identification number for proper recognition as some of them may be of same dimension.

3.6.3 Subsystem Description:

In the subsequent subsections the different subsystems of the proposed simulation model with reference to computer package are discussed in detail.

3.5.3.1 Initialization:

All the variables representing different counts are initialized as one or zero depending upon the purpose for which they are to be used. Matrices alongwith arrays are initialized as -1 to represent the beginning of simulation.

It is assumed that the blood centre will be having some previous stock consisting of units of varying age. This information is normally available with the blood centre and in absence of this information, the units of different age varying between 1 to 17 days are generated randomly using uniform distributions such that the number of units of any age may be between 0 and 3 in accordance with the assumption made in Section 3.4. A new permanent bottle number (PBN) is assigned to each unit and the Match Matrix (MM) is updated accordingly.

3.5.3.2 Procurement

It is an essential input to the blood centre management system. The procurement of blood is through voluntary donors. Occasionally special camps are arranged by blood centre for collection of blood.

The number of units collected will be known to the blood centre and in absence of this information, it is generated randomly using uniform distribution in the range specified in assumption (Section 3.4). For the purpose of simplicity in analysis it was assumed that the collection is of fresh units only. This assumption is a valid practical assumption as in most of the cases the collection is mainly from donors. Each unit after some test and group classification is assigned a permanent bottle number (PBN) and is entered into the unassigned stock. The Match Matrix (MM) and related variables are updated accordingly.

3.5.3.3 Return of Unused But Called Units:

In this subsystem the units which were called earlier by the hospitals for transfusion purposes and could not be used due to some reason or the other (which may be due to less actual need by the patient) are returned to the blood centre. Depending upon the age of the returned units they are either allocated to the unassigned stock or outdated stock.

The number of units returned (NOBR) and their actual unit numbers will be made available to the 'blood centre by the hospitals and in absence of this information, for model analysis, the number of units returned (NOBR) is randomly generated using uniform distributions in the range equal to the number of units called three days back. To know the actual unit numbers of the units returned from the hospitals the array containing the information about units called three days back is identified and the (NOBR) units are selected from this array in a random fashion.

3.5.3.4 Call of Units:

The call of units starts from the second day of the simulation as only the reserved units can be called. The holding period for reservations has been assumed to be 3 days, i.e., a unit once reserved cannot be reserved for another request within three days of the last reservation of a unit.

The array (CBARAY) is updated by purging the unit numbers which were in this array for three days and entering the unit numbers reserved on previous day. The number of units called along with their unit numbers is supplied by the hospitals and in absence of this information, the number of units called is randomly generated using uniform distributions in the range equal to the number of units available in the array (CBARAY).

The actual unit numbers to be issued to hospitals is selected in a random fashion from array (CBARAY). The units are checked for their status. If the status of the unit is found to be 2, i.e., it has been doubly matched with another unit, then actually the older of the two paired units is sent to the hospital provided it satisfy the age restrictions. Three arrays (CBNA), (CBNB) and (CBNC) are maintained to record the information regarding the unit numbers called on each of the last three days, if any. Array (CBNA) contains the unit numbers called on the day, whose day number equals integer multiple of 3 plus one. Array (CBNB) contains the unit numbers called on the day, whose day number equals integer multiple of 3 plus two. Array (CBNC) contains the unit numbers called on the day, whose day number is integer multiple of 3. The proper array to enter information about the called units is selected and updated. The count for total number of units called and the array (NUCALD) are also updated.

3.5.3.5 Cancellation of Reservation:

In this subsystem the reservations of units which were reserved 3 days back and could not be called within that period is cancelled. These cancelled units either join the unassigned stock or outdated stock depending upon their age.

In the simulation model the units reserved 3 days back are checked for their status. If the status is found to be 1, the age of the unit is checked and if the unit is within reuse age limit, the unit number of this unit is entered in the array (RETBNA), otherwise declared outdated. The status is accordingly updated. However, if the status was found to be 2, i.e., the unit is paired with another unit, the paired unit's unit number is entered in an array (RDCMBN), to be used latter in the pair formation of double cross match strategy and the status is updated as 1. Next the second unit in the pair is checked for its age and if this unit is within reuse age limit, the unit number is entered in an array (RETBNA) otherwise declared out-dated. The status is updated accordingly.

3.5.3.6 Reservations:

In this subsystem reservations are done against the requests made by the hospitals. If the demand, i.e., the request for reservations cannot be met fully, it is met in part as far as possible using FIFO policy. The unfulfilled demand is declared as shortage. Hospitals are informed

accordingly. However if the hospital considers it necessary, it can again send the same request the following day. Such request for reservation are satisfied with by assigning the highest priority by the blood centre. An attempt is made to satisfy reservation requests firstly from the units which are returned from hospitals and then, if necessary, from the unreserved units. It is contemplated that above strategy would result in better utilization of the procured blood and in turn would also satisfy the demands more efficiently.

The number of patients and the units requested for each of them is supplied by the hospitals and in absence of this information the number of patients and the number of units demanded by each of them, are randomly generated using uniform distributions and the ranges taken as 1-13 and 1-4 respectively as stated in Section 3.4.

The array (RBARAY) is updated to enter the present day's satisfied requests for reservations. Depending upon the availability of units in unassigned stock, request for reservation of units is met by reserving first the units stored in an array (RETBNA) against the request made using FIFO policy. The array (RBARAY), Match Matrix (MM), Demand Matrix (DM) and related count variables are updated accordingly. The updated Demand Matrix (DM) may be printed for details and information to be sent to hospitals.

Double Cross Matching:

Double cross matching is done for the units reserved by the single cross matching strategy. It should be noted that in general double cross matching has imbedded into it the reservations by single cross matching. For every satisfied request, the units are identified and the patients for whom these units are reserved is declared as the primary patient. An attempt is made to generate pairs among the units reserved by single cross matching using the double cross matching strategy.

The pairs are generated such that there exists a certain minimum age difference among the paired units. The optimal lower limit for the age difference can be determined based on the wastage reduction criterion. The benefit of double cross match in terms of wastage reduction mainly depends on the issue of older paired unit in place of request for younger age paired unit. Further it is contemplated that the chances of wastage reduction improves with

- (1) increase in the number of pairs formed by the double cross matching strategy,
- (2) increase in the call for younger units by the hospitals.

The number of possible pairs that can be formed depends on the following:

- (i) Number and age distribution of singly reserved units.
- (ii) Number and age distribution of initial stock.
- (iii) Procurement distribution of units.
- (iv) The age difference between the paired units.

For pair formation the string of singly cross matched units, which contains units arranged in decreasing order of their age is split into two parts at the middle. The two parts of string are referred as string A and string B. The first unit in the string A is compared with the first unit in string B. If the age difference is appropriate, then the pair is formed, otherwise the unit of string A is compared with the subsequent unit in string B till the pair formation becomes admissible. On getting success in pair formation the status of paired unit is made 2 and the matrices (MM) and (ASINED) are updated accordingly along with related count variable. Similar procedure is repeated for other pair formation from string A. Further while searching for units in string B, for pair formation, if all the units of string B are exhausted without obtaining a pair, the pair formation is not carried out for all the subsequent units in string A.

Age Updating:

In the model the age of units are updated at the end of day's analysis. The units which exceed the age limit for reservation are declared outdated on account of natural aging. The Match Matrix (MM) and related count variables are updated accordingly.

3.5.3.7 Statistics:

The computer package permits the printing of various daily statistics which include COLECT, TCLECT, TBD, TNP, TBFA, ASIND, TCALL, TSORTG, TBDAP, TUNCAL, TCNUSE, ODATE, TUNCGW, TCNUGN, TAGW, UNASND along with the day number (DN). At the end of a simulation run the various statistics are printed. These statistics are defined below:

Average bottle demanded per patient (AVBDPP)

$$= \frac{\text{Total bottle demanded (TBD)}}{\text{Total number of patients (TNP)}}$$

Percentage Shortage (SORTP)

$$= \frac{\text{Total shortages of units (TSORTG)}}{\text{Total bottles demanded (TBD)}} \times 100$$

Percentage wastage with respect to demand (WASTPD)

$$= \frac{\text{Actual number of units outdated (ODATE)}}{\text{Total bottles demanded (TBD)}} \times 100$$

Percentage wastage (WASTPC)

$$= \frac{\text{Actual number of units outdated (ODATE)}}{\text{Total units collected (TCLECT)}} \times 100$$

Percentage call (CALLP)

$$= \frac{\text{Total number of units called (TCALL)}}{\text{Total number of singly met reservations (TBSA)}} \times 100$$

Percentage unused (UNCALP)

$$= \frac{\text{Total number of called units not used (TCNUSE)}}{\text{Total number of units called (TCALL)}} \times 100$$

Percentage unreserved (UNRESP)

$$= \frac{\text{Total number of units not called, (TUNCAL)}}{\text{Total number of singly met reservations (TBSA)}} \times 100$$

Percentage increase in utilization efficiency (UEFFIN).

$$= \frac{\text{Singly met reservations} - \text{Minimum number units actually reserved}}{\text{Singly met reservations}}$$

$$= \frac{(TBSA) - (ASIND)}{TBSA} \times 100$$

Average inventory position (AVINVP)

$$= \frac{\text{Sum of each days unassigned stocks}}{\text{Number of days considered for a simulation}}$$

3.6 STRATEGIES EVALUATION APPROACH

The two matching strategies viz., single cross matching and double cross matching have been evaluated using the randomly generated data for both 1 day and 3 days reservation holding periods. The two computer packages were developed for the

simulation model, one with reservation holding period as 3 days and the other with reservation holding period as 1 day. The program was written in Fortran IV for IBM 7044-1401 systems. Five different random number generators have been used, which give uniformly distributed random numbers between 0 and 1. The parameters have been made to lie within desired range of values by the use of appropriate multiplication factor. The relative performance of these strategies are presented in the next chapter. The listings of the computer package developed for two reservation holding periods 1 and 3 days are given in Appendix II and Appendix I.

Each simulation run is carried for a particular minimum age difference among the paired units for double cross match strategy. The pseudo random numbers used for getting random information with uniform distribution is initialized at the beginning of each simulation run.

The two strategies have also been evaluated based on the data obtained from Red Cross unit, Poona and Blood Bank Section of Sasson Government Hospital, Poona. The details of the case study along with the results obtained are presented in next chapter.

CHAPTER 4

EVALUATION OF STRATEGIES: RESULTS AND CONCLUSIONS

The model developed in previous chapter and the computer packages prepared for the same were used for studying the relative performances of the two matching strategies for 1 day and 3 days reservations holding periods. Further the performance of DCM strategy for various minimum pair age difference was studied. The results were obtained separately for the generated data and the case study.

For the study based on generated data, the data has been generated using five different pseudo random number generators, keeping in view the suitable ranges of the various parameters. The ranges selected for the parameters have already been mentioned in Section 3.4.

For the case study, the data were collected from the Red Cross unit, Poona and the Blood Bank Section of Sasson Govt. Hospital, Poona. Since the blood banks in India are mainly concerned with the collection of blood and not as in USA and European countries, with the overall management of it, the data collected could not give all the information needed for the simulation model. All the collected information has been used

and other necessary information has been generated suitably keeping the various assumptions listed in Section 3.4 in view. The results obtained for both the generated data and the case study have been analysed.

4.1 RESULTS FOR GENERATED DATA:

For the generated data, the results of forty eight simulation runs obtained for 1 day and 3 days reservation holding periods using single cross matching and double cross matching strategies are presented in Tables 4.1 and 4.2. Each run corresponds to a particular DCM pair minimum age difference varying from 3 to 14 days.

Figures 4.1 and 4.2 graphically represent the percentage increase in utilization efficiency and percentage wastage versus DCM pair minimum age difference respectively, using the results listed in Tables 4.1 and 4.2. As the percentage shortage was zero in all situations, the same has not been shown graphically.

On the basis of results obtained, the following observations are made.

- (i) There was no shortage in any situation.
- (ii) Both the percentage increase in utilization efficiency and percentage wastage are more for 1 day holding period compared to 3 days holding period for reservations.

Table 4.1: Results for generated data using single cross match strategy.

Reservation Holding period (in Days)	Percentage Shortage	Percentage Wastage	Percentage increase in Utilization Efficiency
1	0.0	28.32	31.05
3	0.0	14.34	19.96

Table 4.2: Results for generated data using double cross match strategy.

DCM Pair		Holding period for reservation				
Min. Age	Difference	3 Days			1 Day	
(in Days)		Perce- tage Shor- tage	Perce- tage Wastage	Perce- tage incre ase in uti- lization efficiency	Perce- tage Shor- tage	Perce- tage wastage increase in utili- zation efficiency
14		0.0	14.34	19.96	0.0	28.32
13		0.0	14.34	19.96	0.0	28.32
12		0.0	14.34	19.96	0.0	28.32
11		0.0	14.34	19.96	0.0	28.44
10		0.0	14.45	19.96	0.0	28.55
9		0.0	14.45	19.96	0.0	28.44
8		0.0	14.45	19.76	0.0	29.60
7		0.0	14.45	19.96	0.0	27.98
6		0.0	14.57	19.56	0.0	27.86
5		0.0	14.57	19.96	0.0	30.17
4		0.0	5.20	21.17	0.0	29.71
3		0.0	11.79	21.77	0.0	28.55

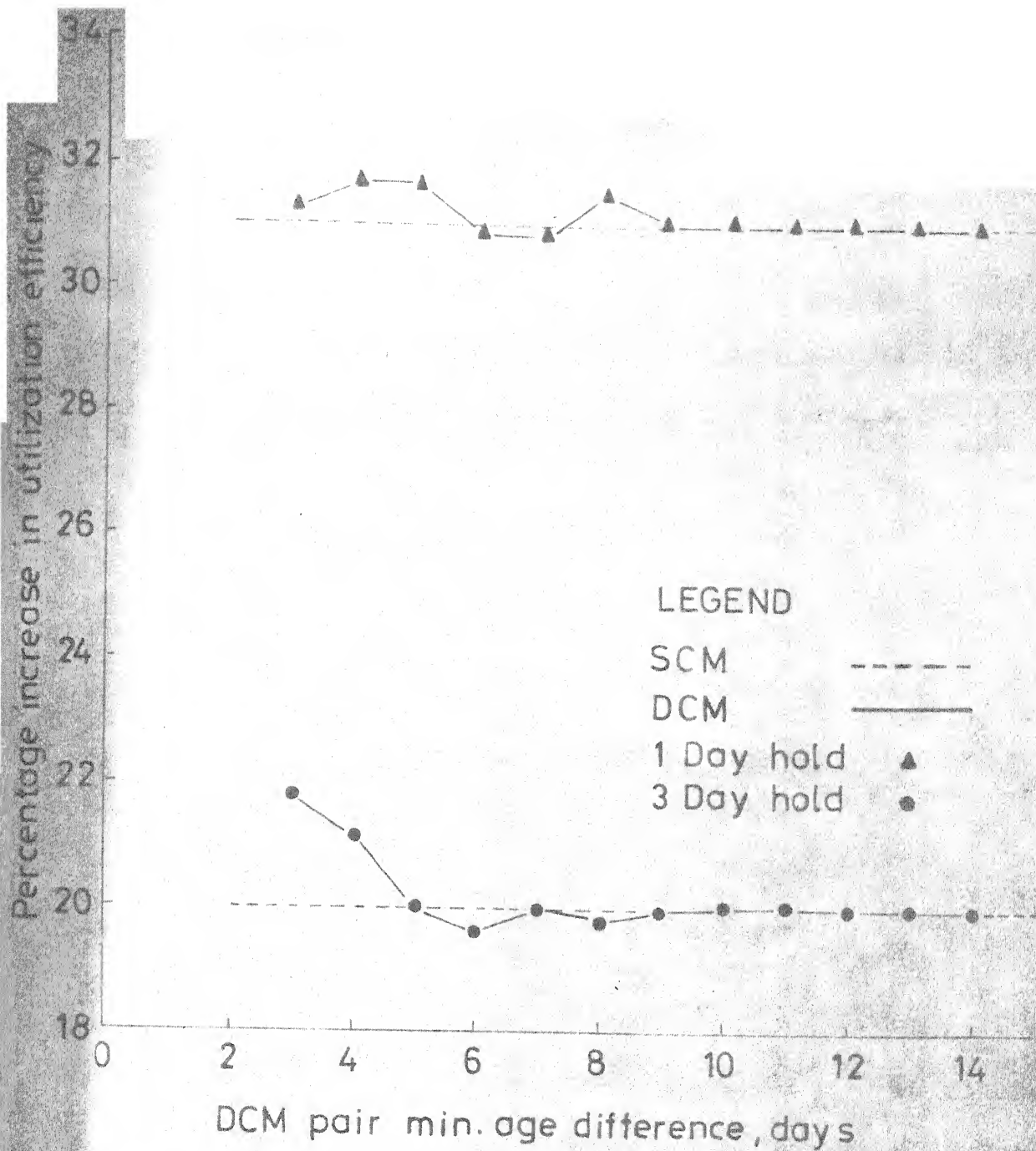


Fig.4.1 Comparison of increase in utilization efficiency for SCM & DCM (Generated data)

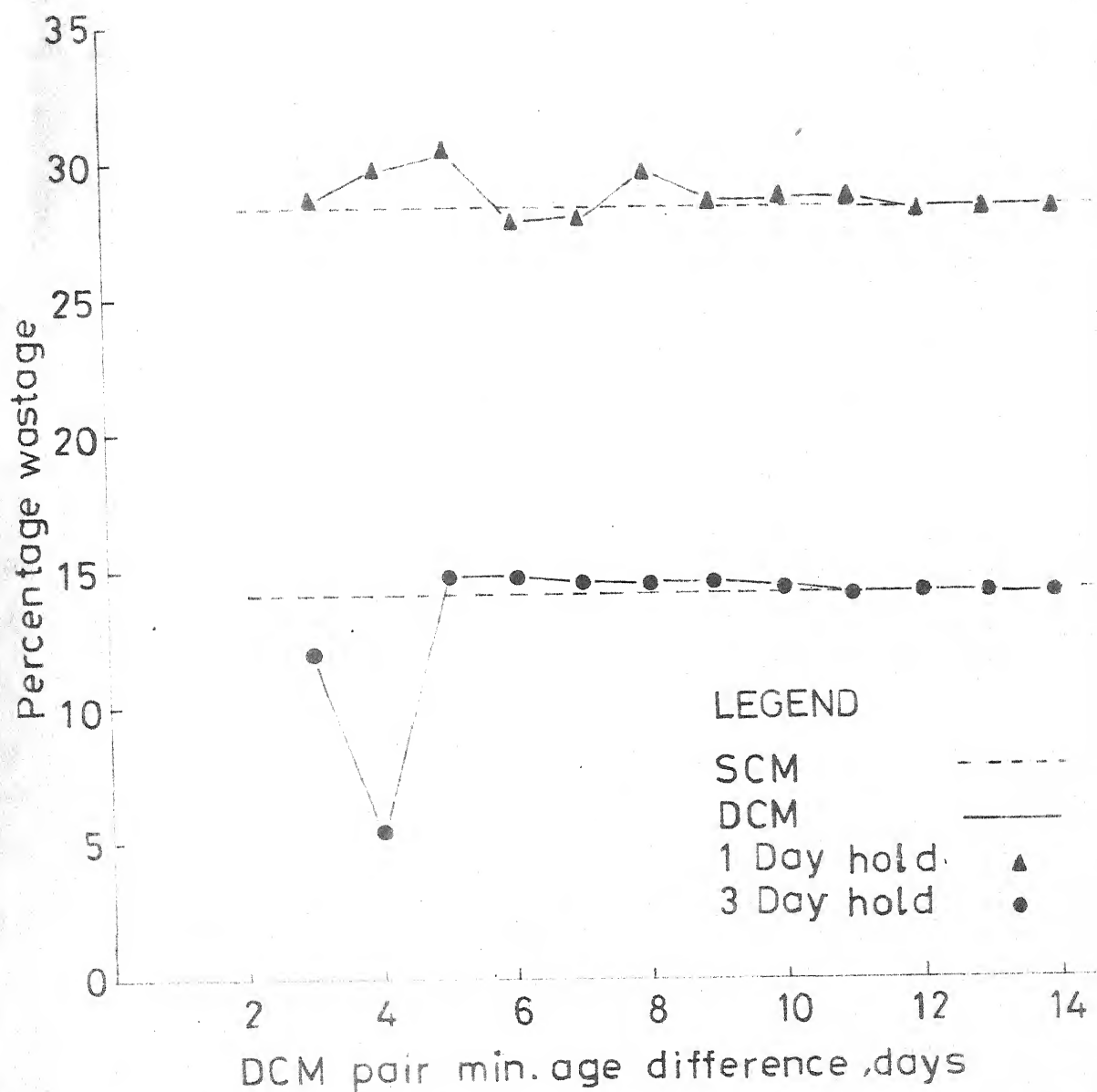


Fig.4.2 Comparison of percentage wastage for SCM & DCM (Generated data)

(iii) The minimum wastage was 5% for 3 days holding period for reservation, using double cross match strategy with minimum age difference among pairs as 4 days. The corresponding increase in utilization efficiency was 21%.

On the basis of the results obtained, the use of double cross match strategy is suggested with 3 days holding period for reservation and DCM pair minimum age difference as 4 days.

4.2 RESULTS FOR CASE STUDY

The results obtained for the case study with 1 day and 3 days holding period for reservation using single and double cross matching strategies are presented in Tables 4.3 and 4.4. For each holding period for reservation twelve simulation runs were carried out for single cross matching and another twelve simulation runs for the double cross matching. Each run corresponds to a particular DCM pair minimum age difference. The values selected varied in the range 3 to 14 days.

The results obtained have also been represented graphically. Figures 4.3 to 4.5 graphically represent the percentage shortage, the percentage wastage and percentage increase in utilization efficiency versus DCM pair minimum age difference respectively, using results listed in Tables 4.3 and 4.4.

Table 4.3: Results for case study data using single cross match strategy.

Reservation Holding Period (in Days)	Percentage Shortage	Percentage Wastage	Percentage Increase in Utilization Efficiency
1	6.45	13.28	46.98
3	14.92	5.65	27.49

Table 4.4 Results for case study data using double cross match strategy.

DCM Pair Min.Age Difference (in Days)	Holding period for reservation					
	3 Days			1 Day		
	Percentage Shortage	Percentage Wastage	Percentage Increase in Utilization Efficiency	Percentage Shortage	Percentage Wastage	Percentage Increase in Utilization Efficiency
14	9.48	5.37	30.96	6.45	12.71	47.41
13	8.06	5.93	30.70	4.84	14.69	45.13
12	15.12	7.63	28.27	4.44	13.84	46.62
11	11.90	6.50	33.18	4.64	14.41	45.88
10	16.53	7.06	23.91	7.06	14.12	46.64
9	11.90	6.50	33.64	6.65	12.71	47.95
8	15.52	6.78	29.83	6.25	12.99	46.67
7	9.88	5.93	31.54	4.03	15.25	46.85
6	14.72	8.19	31.21	6.05	14.69	44.21
5	9.48	5.08	29.40	6.25	12.71	47.31
4	12.50	4.24	28.11	4.84	12.15	45.55
3	12.90	7.34	31.94	6.25	12.99	46.67

The following observations are made from these graphs:

- (1) In general, percentage shortage is almost double for reservation holding period as 3 days as compared to the same as 1 day for both single and double cross matching strategies. In single cross matching strategy the percentage shortages were 14.92 and 6.45 for reservation holding periods as 3 days and 1 day respectively. In double cross matching strategy, the minimum shortages occurred for minimum pair age difference of 13 days and 7 days for reservation holding period as 3 days and 1 day respectively. The corresponding values for shortage were 8.06% and 4.03%.
- (ii) In most of the cases, the double cross matching strategy resulted in less shortage (in percentage) as compared to the single cross matching strategy.
- (iii) For both the strategies, in general, percentage wastage are almost double for reservation holding period of 1 day as compared to same of 3 days. In double cross matching the minimum percentage wastages were 4.24 and 12.15 corresponding to reservation holding periods as 3 days and 1 day.
- (iv) For both the strategies, the percentage increase in utilization efficiency is more for reservation holding period as 1 day compared to the same as 3 days.
- (v) For reservation holding period as 3 days the percentage increase in utilization efficiency is more for the double cross matching compared to the single cross-matching. However, the

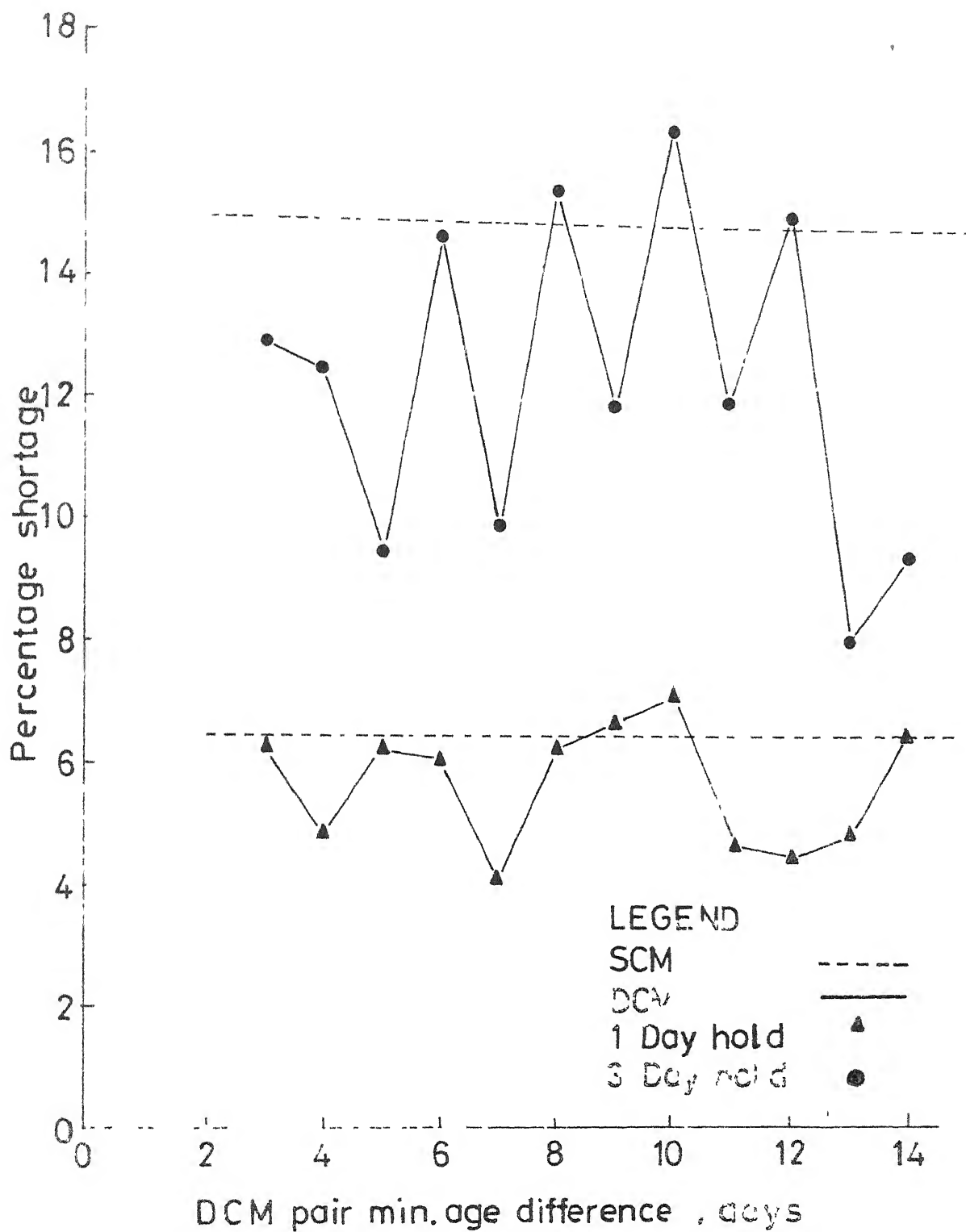


Fig. 4.3 Comparison of percentage shortage for SCM & DCM (Case study)

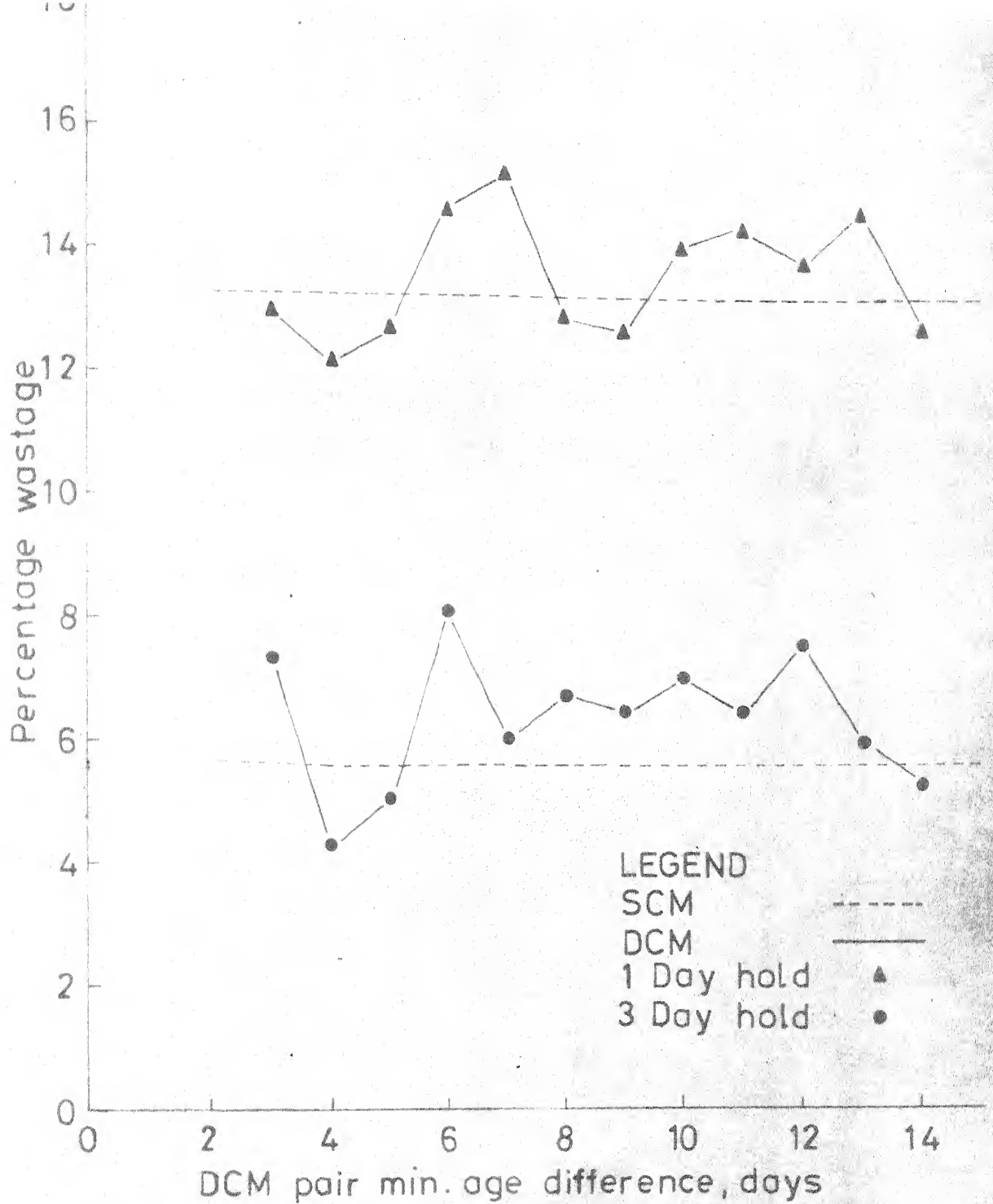


Fig.4-4 Comparison of percentage wastage for SCM & DCM (Case study)

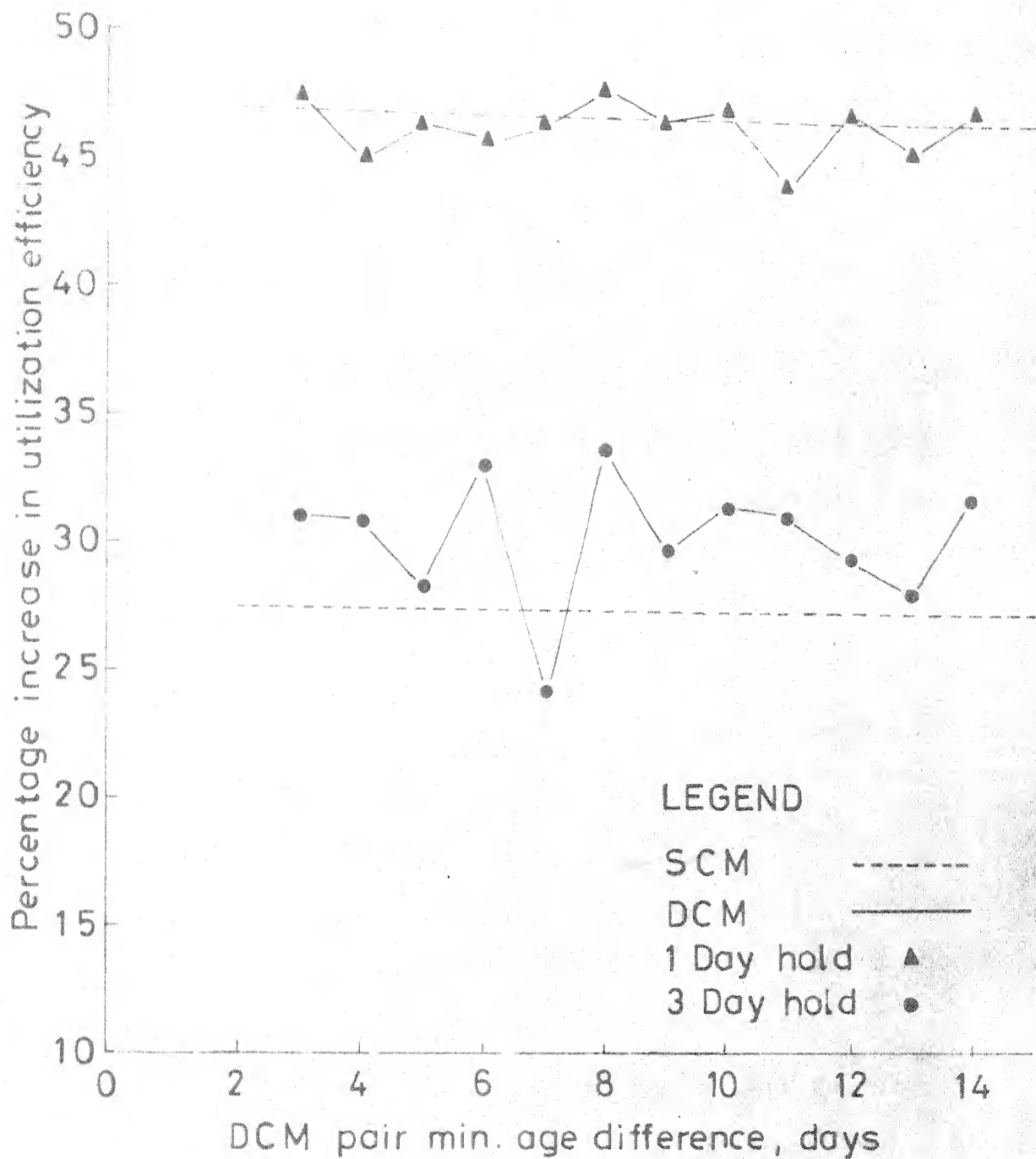


Fig. 4.5 Comparison of increase in utilization efficiency for SCM & DCM (Case study)

percentage utilization efficiency for reservation holding period as 1 day is more in the case of single cross matching compared to double cross matching.

The results of the case study suggest the following.

- (1) If shortage used as criterion, the double cross matching strategy should be adopted with DCM pair minimum age difference as 7 days and reservation holding period as 1 day.
- (2) If wastage is to be used as criterion, adoption of single cross matching strategy is recommended with reservation holding period as 3 days.
- (3) If the increase in utilization efficiency is to be used as criterion, the single cross match strategy should be adopted using 1 day holding period for reservation.
- (4) Considering shortage, wastage and increase in utilization efficiency equally important the use of double cross matching strategy is suggested with pair minimum age difference as 4 days and reservation holding period as 1 day.

In both the case of generated data as well as case study the wastage reduction could not be achieved due to less number of actual call for younger paired units, which first of all depend on the number of double cross matched pairs formed.

4.3 COMPARISON OF COMPUTATIONAL TIMES:

The execution time requirements for single cross matching and double cross matching strategies using generated and case study data are listed in Table 4.5. The execution time requirements are based on twelve simulation runs each for the cases of reservation holding period as 1 day and 3 days.

Table 4.5. Execution times for twelve simulation runs.

Data	Reservation holding period (Days)	Time in Seconds		Percentage increase from SCM
		SCM	DCM	
Generated	1	20	22	10
	3	22	28	27.2
Case study	1	14	16	14.3
	3	18	23	21.7

On the basis of above table it is observed that for the generated data as well as the case study the execution times for 3 days holding period for reservation were more compared to the reservation holding period as 1 day irrespective of the strategy adopted. Further as has already been pointed out, the percentage wastage is less when 3 days holding period for reservation is used, slight increase in computer time can be justified.

As expected, in all situation the double cross matching strategy takes more time compared to single cross matching strategy.

4.4 CONCLUSIONS:

The results based on the generated data and case study indicate that in most of the cases the performance of double cross matching strategy is slightly better than single cross matching in terms of higher percentage utilization efficiency and lower shortage. However, it was observed that for both the generated data and the case study, the blood wastages were somewhat higher for most of the DCM pair minimum age differences considered as compared to the single cross matching strategy.

Based on the study, the adoption of double cross matching strategy is recommended for Regional Blood Centres.

4.5 SCOPE FOR FUTURE WORK:

Whenever we move in some direction for the fulfilment of certain objectives, even after getting the same, it is usually observed that new horizons emerge towards which further effort may be directed. Present work also could not escape the similar happening and as such the future work may be taken up in the following directions.

i) As mentioned in Section 3.3.2, in the present work only two holding periods for reservations viz., 1 day and 3 days were considered. However, it would be worthwhile to study the influence of other values of reservation holding periods on wastage, shortage and increase in utilization efficiency with a view to determine optimal value of reservation holding period.

ii) In the present work, the double cross match pair formation was done using minimum age difference among paired units as criterion. An alternative strategy for pair formation could be to form pairs out of a fixed percentage of older and younger units among singly reserved units. The performance of such a strategy needs to be evaluated.

iii) Extending the basic concept of double cross matching, one may evolve a multiple cross matching policy. In the multiple cross matching strategy, each cross matched unit of the multiplet will be reserved in the name of more than two patients and in the event of calls, older units would be issued to the patients in order of their call for the unit. It is possible that the multiple cross matching strategy will further significantly reduce the wastage but this may involve considerably more number of cross matches to be performed along with computational and book keeping effort.

iv) The present work is confined to the management of blood for a regional blood centre. However, it would be desirable to develop computer oriented integrated systems for the management of blood at the state level (comprising of many regional blood centres) and then for the country as a whole in order to use this scarce, life saving, perishable commodity in the most efficient way.

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\$JCB MEG371, TIMEQCR, PAG15010, NAME, SHEKHAR
\$IBJCB
\$IBFTC MAIN

APPENDIX. 1

CM SAIRAM
EVALUATION OF STRATEGIES FOR THE MANAGEMENT OF REGIONAL BLOOD CENTRE
COMPUTER PACKAGE WITH 3 DAYS RESERVATION HOLDING PERIOD
BY

INTEGER TBC, TAP, TSCRIPTG, TCALL, TUNCAL, TCONUSE, TBDAP
INTEGER CN, CPN, CBN, FBN, PBN, RBN, ABN, COLLECT, RNI
INTEGER TBSA, TPSA, TCOLLECT, CBN, CHH
INTEGER UNASND, ASIND, COATS, TUNCGW, TCONUGW, TAGW
INTEGER PRCCUR(10), IST(20)
INTEGER INTAKE(50), DEMAND(50), NUCALD(60)
INTEGER CBN4(60), CBN5(60), CBN6(60)
INTEGER RETBNA(60), PCMBN(60)
INTEGER CBN4AY(150), CBN5AY(150)
INTEGER NM(500, 2), ASINED(700, 2), DM(50, 5)
INTEGER AX, AY, AV, AW, AZ
COMMON /4/ AX, AY, AV, AW, AZ

101 FORMAT(20I4)
102 FORMAT(15X, 21I3)
105 FORMAT(15X, *----- DAY NO...*, I4)
108 FORMAT(1H1, 14X, *RESULTS WITH SINGLE CROSS MATCH, 3 DAY HOLD*, //)
109 FORMAT(1H1, 14X, *RESULTS WITH DOUBLE CROSS MATCH, 3 DAY HOLD*, //)
110 FORMAT(15X, 30I4)
115 FORMAT(15X, 10I6)
116 FORMAT(1H1, 14X, 8F6.2, 2F7.3, F6.2)
120 FORMAT(15X, *NO RETURN OF CALLED BLOOD ON DAY NO....*, I4)
121 FORMAT(15X, *NO BOTTLE CALLED ON DAY NO.....*, I4)
122 FORMAT(15X, *NO DOUBLE CROSS MATCH ON DAY NO....*, I4)

*** DESCRIPTION OF VARIABLES USED ***

CN ... DAY NUMBER OF A SIMULATION RUN
FBN ... PERMANENT BOTTLE SEQUENCE NUMBER LABELED BY THE CENTRE
COLLECT ... COLLECTION OF FRESH UNITS ON A DAY BY THE CENTRE
TBC ... TOTAL NUMBER OF BOTTLES DEMANDED FROM THE CENTRE
TAP ... TOTAL NUMBER OF PATIENTS FOR WHOM RESERVATION REQUESTS CAME
TSCRIPTG ... TOTAL NUMBER OF SHORTAGES OF UNITS AT THE CENTRE
TCALL ... TOTAL NUMBER OF UNITS CALLED FROM THE CENTRE
TUNCAL ... TOTAL NUMBER OF UNITS NOT CALLED FROM THE CENTRE
TCONUSE ... TOTAL NUMBER OF UNITS CALLED BUT NOT USED BY THE HOSPITALS
TBDAP ... TOTAL NUMBER OF BOTTLE DOUBLY ASSIGNED PAIRS MADE AT THE CENTRE
TCOLLECT ... TOTAL NUMBER OF UNITS COLLECTED BY THE CENTRE
TBSA ... TOTAL NUMBER OF BOTTLES SINGLY ASSIGNED BY THE CENTRE

```

C      TFSA ...TOTAL NUMBER OF PATIENTS, SIMPLY ASSIGNED BY THE CENTRE
C      TUNCGW...TOTAL NUMBER OF UNITS NOT CALLED AND ARE GOING WASTE
C      TCNCGW...TOTAL NUMBER OF CALLED UNITS NOT USED AND ARE GOING WASTE
C      TAGW ...TOTAL NUMBER OF UNITS ACTUALLY GOING WASTE DUE TO AGING ONLY
C      UNASNC...TOTAL NUMBER OF UNASSIGNED UNITS AVAILABLE AT THE CENTRE
C      ASIANC ...MINIMUM NUMBER OF UNITS ASSIGNED FOR REQUESTS MET BEFORE
C      CCATE ...TOTAL NUMBER OF UNITS OUTDATED IN THE SYSTEM
C      NOPR ...NUMBER OF PATIENTS REQUESTING FOR RESERVATION ON A DAY
C      NCBC ...NUMBER OF BOTTLES CALLED ON A DAY BY THE HOSPITALS
C      NCBR ...NUMBER OF BOTTLES RETURNED ON A DAY BY THE HOSPITALS
C      ****
C      -----
C      ****
C      PRINT 108
C      NFCCNS=1
C      CALL TIME(MLW)
C      IXX=C
123  CCNTINUE
C      SIMNC=13.
C      SIMNC=1.
C      NCDECN=14
124  CCNTINUE
C      NNN=1
C      CALL INRANE(NNN)
C      DO 125 I=1,21
C      PRCCUR(I)=0
125  1ST(I)=0
C      DO 125 I=1,50
C      CM(I,1)=-1
C      CM(I,2)=-1
C      CM(I,3)=-1
C      CM(I,4)=-1
135  CM(I,5)=-1
C      DO 145 I=1,60
C      NUCAEC(I)=-1
C      IF(SIMNC.GT.24.)INTAKE(I)=-1
C      DEMAND(I)=-1
C      CBNA(I)=-1
C      CBNE(I)=-1
C      CENC(I)=-1
C      RDCMEN(I)=-1
145  RETENA(I)=-1
C      DO 150 I=1,750
C      REARAY(I)=-1
150  CBARAY(I)=-1
C      DO 155 I=1,700
C      ASINED(I,1)=-1
C      ASINED(I,2)=-1
155  ASINED(I,3)=-1
C      DO 165 I=1,900
C      MM(I,1)=-1
C      MM(I,2)=-1
C      MM(I,3)=-1
C      MM(I,4)=-1
165  MM(I,5)=-1
C      T80=0

```

```

TNP=0
TSCRTG=0
TCALL=0
TUNCAL=0
TCNUSE=0
TECAP=0
TCLECT=0
ASINC=0
CCATE=0
TUNCGW=0
TCNUGW=0
TAGW=0
K2=0
UNASNC=0
TESA=0
NA=0
LF=0
LC=0
LX=0
INCCN=0
LA=0
FFN=1
AEN=1
DN=1
N4=0
NTLW=0
LSP=0
RETEA(4)=0
*****
INITIAL STACKING
*****
PRINT 105,DN
IF(INCCN.EC.(-1)) GO TO 250
CC 175 I=18,21
175 IST(I)=C
CC 195 L=1,17
K=18-L
IST(K)=RACYX(AX)*4.
IN=IST(K)
IF(IN.EC.C) GO TO 195
N3=N4+1
N4=N4+IN
CC 185 I=N3,N4
PEN=I
MM(PEN,1)=1
MM(PEN,2)=K
MM(PEN,3)=0
185 CCNTINUE
195 CCNTINUE
C PRINT 102,(IST(I),I=1,21)
INCCN=-1
UNASNC=UNASNC+N4
K4=N4
-----
*****
PROCUREMENT

```

C
C

IF(IXX.NE.0) GO TO 250
IF(SIMNC.NE.1.) GO TO 250
READ 101,(INTAKE(I),I=1,20)
250 CONTINUE
IND=CN-CN/3*2
IF(IND.EQ.0) IND=7
CCLECT=ANDYX(AX)*EI.
IF(IXX.NE.0) GO TO 250
IF(SIMNC.EQ.12.) INTAKE(CN)=CCLECT
255 CONTINUE
IF(SIMNC.LE.24.) CCLECT=INTAKE(CN)
IF(CCLECT.EQ.0) CCLECT=1
PROCUR(1)=CCLECT
INTAKE(CN)=CCLECT

C
C

STOCK ENTRY
K3=K4+1
K4=K4+CCLECT
CC 245 I=K3,K4
PEN=1
NM(I,1)=I
NM(I,2)=1
NM(I,3)=0

265 CONTINUE
280 TCLECT=K4
UNASAD=UNASNE+CCLECT

C
C

C
C

RETURN OF UNUSED CALLED BOTTLES

C
C

LKR=5
JX=6
JY=6
IF(CN.LE.4) GO TO 355
BR=NUCALC(CN-3)
NCBP=ANDYV(AV)*BR
LX=NCBP
LY=0
IF(LX.EQ.0) GO TO 350
IF(IND.EQ.1) GO TO 330
IF(IND.EQ.2) GO TO 250
LY=CENC(3)-5
IF(LY.LE.0) GO TO 350
IF(LX.GT.LY) LX=LY
CC 320 JU=1,LX
RBN=CBNC(JU+5)
NM(RBN,3)=0
NM(RBN,4)=0
IF(NM(RBN,2).LE.17) GO TO 215
NM(RBN,5)=0
TCNUGW=TCNUGW+1
CCATE=CCATE+1
GO TO 320

```

315 UNASND=UNASND+1
   MM(REN,5)=-2
   RETENA(JX)=RBN
   JX=JX+1
320 CONTINUE
   GO TO 397
330 LY=CBNA(3)-5
   IF(LY.LE.0) GO TO 390
   IF(LX.GT.LY) LX=LY
   CC 340 JW=1,LX
   RBN=CBNA(JW+5)
   MM(RBN,2)=0
   MM(RBN,4)=0
   IF(MM(RBN,2).LE.17) GO TO 355
   MM(RBN,5)=0
   TCNUGW=TCNUGW+1
   CDATE=CDATE+1
   GO TO 340
335 UNASND=UNASND+1
   MM(REN,5)=-2
   RETENA(JX)=RBN
   JX=JX+1
340 CONTINUE
   GO TO 397
350 LY=CBNB(3)-5
   IF(LY.LE.0) GO TO 390
   IF(LX.GT.LY) LX=LY
   CC 360 JW=1,LX
   RBN=CBNB(JW+5)
   MM(RBN,3)=0
   MM(RBN,4)=0
   IF(MM(RBN,2).LE.17) GO TO 355
   MM(RBN,5)=0
   TCNUGW=TCNUGW+1
   CDATE=CDATE+1
   GO TO 360
355 UNASND=UNASND+1
   MM(REN,5)=-2
   RETENA(JX)=RBN
   JX=JX+1
360 CONTINUE
   GO TO 397
390 CONTINUE
   PRINT 120,CN
   IF(LY.LE.0) GO TO 398
397 TCNUSE=TCNUSE+LX
398 RETENA(3)=JX-1
   RETENA(1)=CN
   RETENA(4)=3
   LKR=RETENA(3)
399 CONTINUE

```

C
C
C
C
C

```

*****
-----
CALL OF BOTTLES
-----
*****

```

```

LTP=SC0
IF(CN.EC.1) GO TO 490
IF(CN.GT.4) GO TO 412
IF(CN.GT.2) GO TO 413
CC 401 I=1,M2
401 CBARAY(I)=RBARAY(I)
GO TO 415
402 IF(CN.GT.2) GO TO 403
J12=L2-L1
CC 404 I=1,J12
M1=M1+I
LI=L1+I
404 CBARAY(M1)=RBARAY(LI)
M3=M1
GO TO 415
405 J23=L3-L2
CC 408 I=1,J23
M1=M2+I
LI=L2+I
408 CBARAY(M1)=RBARAY(LI)
M3=M1
GO TO 415
412 IH=M3-M1
IF(M3.EC.M1) GO TO 4130
CC 413 I=1,IH
IL=I+M1
413 CBARAY(I)=CBARAY(IL)
M1=M2-M1
M2=IH
GO TO 4131
4130 M1=0
M2=0
IH=0
4131 CCNTINUE
IJ=L3-L2
CC 414 I=1,IJ
IH=IH+I
IMM=L2+I
414 CBARAY(IM)=RBARAY(IMM)
M3=IH
415 NCBC=1.+RNDYZ(AZ)*50.
LC=NCBC
LD=M3
IF(LC.LE.3) GO TO 490
IF(LC.GE.LD) GO TO 415
LK=5
LKK=LC+5
CC 480 JJ=1,LC
A3=M3
416 CBH=1.+RNDYW(AW)*A3
CBN=CBARAY(CBH)
LHH=MM(CBN,5)
IF(LHH.EQ.2) GO TO 425
IF(LHH.NE.1) GO TO 479
417 CCNTINUE
IF(CBH.NE.M3) GO TO 419

```

```

IF(M1.EQ.M3)M1=M3-1
IF(CN.LE.2) GO TO 418
IF(M2.EQ.M3)M2=M3-1
418 M3=M3-1
A3=M3
GO TO 450
419 IF(CBH.GT.M1) GO TO 421
M1=M1-1
IF(CN.LE.2) GO TO 421
421 IF(CBH.GT.M2) GO TO 423
M2=M2-1
423 M3=M3-1
A3=M3
CC 424 C=CBH,M3
IK=I+1
424 CEARAY(I)=CEARAY(IK)
GO TO 450
425 KAS=ASINED(CBN,3)
IF(MM(KAS,5).EQ.0) GO TO 437
ASINED(CBN,3)=C
ASINED(KAS,3)=0
MM(CBN,4)=-2
MM(KAS,4)=-2
IF(CBN.LT.KAS) GO TO 430
IF(CBN.LT.LTR)LTR=CBN
MM(CBN,5)=1
CC 427 IK=1,M3
KASN=CEARAY(IK)
IF(KAS.NE.KASN) GO TO 427
CBH=IK
CBN=KAS
GO TO 417
427 CONTINUE
430 MM(KAS,5)=1
GO TO 417
450 MM(CBN,5)=2
455 LK=LK+1
IF(IND.EQ.1) GO TO 460
IF(IND.EQ.2) GO TO 470
CBNC(LK)=CBN
IF(LK.LT.LKK) GO TO 460
CBNC(1)=CN
CBNC(2)=IND
CBNC(3)=LKK
GO TO 495
460 CBNA(LK)=CBN
IF(LK.LT.LKK) GO TO 480
CBNA(1)=CN
CBNA(2)=IND
CBNA(3)=LKK
GO TO 495
470 CBNE(LK)=CBN
IF(LK.LT.LKK) GO TO 480
CBNE(1)=CN
CBNE(2)=IND
CBNE(3)=LKK

```



```

GC TC 495
479 LAB=LC-JJ
IF(LAB.GT.7) GO TO 416
GC TC 494
480 CONTINUE
490 CONTINUE
C PRINT 121,CA
GC TC 495
494 LC=JJ-1
495 CONTINUE
TCALL=TCALL+LC
NUCALD(CN)=LC
C *****
C -----
C CANCELLATION OF RESERVATION
C -----
C *****
IF(CN.LE.3) GO TO 599
DO 590 I=1,LI
LP=REARRAY(I)
IF(LP.EQ.0) GO TO 590
LS=NM(LP,5)
IF(LS.EQ.3) GO TO 590
IF(LS.EQ.0) GO TO 590
IF(NM(LP,2).LE.17) GO TO 520
IF(LS.NE.2) GO TO 515
LPM=ASINED(LP,3)
IF(LPM.LE.0) GO TO 515
NM(LPM,5)=1
ASINED(LPM,3)=-2
ASINED(LP,3)=-2
515 CONTINUE
NM(LP,5)=0
TUNCGW=TUNCGW+1
CDATE=OCATE+1
GC TC 590
520 IF(LS.NE.1) GO TO 540
RETEA(JX)=LP
NM(LP,3)=0
NM(LP,5)=-2
GC TC 580
540 IF(LS.NE.2) GO TO 590
LPA=ASINED(LP,3)
IF(NM(LPA,5).LE.0) GO TO 550
NM(LP,3)=NM(LPA,4)
NM(LP,4)=-2
NM(LP,5)=1
RDCMEN(JY)=LP
JY=JY+1
GC TC 560
550 LPA=LP
560 CONTINUE
RETEA(JX)=LPA
NM(LPA,3)=0
NM(LPA,4)=-2
NM(LPA,5)=-2

```

```

ASINED(LPA,2)=-2
ASINED(LPA,3)=-2
ASINED(LP,2)=LPA
ASINED(LP,3)=-2
580 TUNCAL=TUNCAL+2
UNASND=UNASN(+1)
JX=JX+1
590 CONTINUE
RETEMA(1)=0N
RETEMA(4)=5
RETEMA(3)=JX-1
LKR=RETEMA(3)
RDCMEN(1)=0N
RDCMEN(4)=7
RDCMEN(3)=JY-1
LKS=RDCMEN(3)
599 CONTINUE
*****
-----
RESERVATION
-----
*****
IF(EN.NE.1) GO TO 606
N2=0
K2=0
606 CONTINUE
NCPR=1.+RNDYX(AX)*13.
TNP=TNP+NCPR
NRRC=0
NPT=0
IF(CN.LE.3) GO TO 630
L12=L2-L1
CC 615 I=1,L12
IA=I+L1
615 REARAY(I)=REARAY(IA)
L21=L12+1
L23=L3-L1
CC 625 I=L21,L23
IB=I+L1
625 REARAY(I)=REARAY(IB)
L1=L12
L2=L23
KTR=L2+1
630 N1=N2+1
N2=N2+NCPR
NRRC=0
KZ=5
CC 660 J=N1,N2
NRD=NRD+1
CPN=NRD
PPN=J
RN=1.+RNDYY(AY)*4.
NEREP=RN
K1=K2+1
K2=K2+NEREP
CC 670 KK=K1,K2

```

```

NRR=NRR+1
CEN=KK
CM(NRR,1)=NRR
CM(NRR,2)=NRR
TED=TED+1
IF(UNASNC.GT.C) GO TO 650
NPT=1
CM(NRR,3)=0
CM(NRR,4)=0
CM(NRR,5)=0
NRRSEC=NRR-1
TSCRTG=TSCRTG+1
GO TO 670
650 INDEX=1
IF(CN.LE.3) GO TO 660
KRP=5
KM=PETBNA(3)
IF(KM.LT.6) GO TO 661
NA=KZ+1
IF(NA.GT.KM) GO TO 661
IF(KZ.GT.KM) GO TO 661
DC 656 KR=NA,KM
KN=PETBNA(KR)
KZ=KZ+1
ABN=KN
INDEX=0
KRP=KR
ASINED(ABN,1)=J
ASINED(ABN,2)=ABN
GO TO 663
656 CONTINUE
661 ABN=ASINC+1
662 ASINED(CBN,2)=ABN
ASINED(CBN,1)=J
663 UNASNC=UNASNC-1
CM(NRR,3)=J
CM(NRR,4)=ABN
CM(NRR,5)=1
MM(ABN,5)=1
MM(ABN,2)=J
TBSA=TBSA+1
TPS1=J
IF(CN.GT.3) GO TO 665
REARAY(TBSA)=ABN
GO TO 669
665 REARAY(KTR)=ABN
KTR=KTR+1
669 CONTINUE
IF(INDEX.EQ.0) GO TO 670
ABN=ABN+1
ASINC=ASINC+1
670 CONTINUE
680 CONTINUE
IF(CN.GT.3) L3=KTR-1
685 CEPADC(CN)=NRR
IF(NPT.EQ.0) NRRSPC=NRR

```

```

IF(CN.GT.2) GO TO 691
L3=TESA
M3=L3
IF(CN.NE.1) GO TO 686
L1=TESA
M1=L1
GO TO 691
686 IF(CN.NE.2) GO TO 688
L2=TESA
M2=M1+L2-L1
688 M3=M2+L3-L1
691 CCNT=NUE
IF(UNASNE.LT.0)UNASNE=0
IF(CN.LE.3) GO TO 695
IF(KM.LE.KRP) GO TO 693
LW=KM-KRP
NTLW=NTLW+LW
UNASNE=UNASNE-LW
IF(UNASNE.LT.0)UNASNE=0
695 CONTINUE
IF(NFDCMS.EC.1) GO TO 785
*****
-----
DOUBLE CROSS MATCHING
-----
*****
721 N5=TECAP+1
KX=0
N6=TECAP+(ASINC-TECAP)/2
722 LR=N6
IF(N6.LE.N5) GO TO 788
KLL=6
KP=RDCMEN(3)
CC 767 NN=N5,N6
NR1=NN
IF(CN.LE.3) GO TO 745
IF(KP.LT.6) GO TO 745
IF(KLL.GT.KP) GO TO 745
NR1=RDCMEN(KLL)
KLL=KLL+1
745 IF(MN(NR1,5).EC.1) GO TO 753
NR1=NR1+1
IF(NP1.GT.ASINC) GO TO 788
GO TO 745
753 NR=MN(NR1,2)
JS=MN(NR1,5)
763 NR3=MN(LR,2)
JR=MN(LR,5)
JC=NR-NR3
IF(JC.LT.NDCDCM) GO TO 766
IF(JS.NE.1) GO TO 767
IF(JR.NE.1) GO TO 766
764 NP1=NR3
KT=LR-1
NP2=MN(KT,2)
IF(NP1.NE.NP2) GO TO 765

```

```

AF3=MM(KT,5)
IF(AF3.EQ.2) GO TO 765
LR=LR-1
GO TO 764
765 NR2=LR
MM(NR1,4)=MM(NR2,3)
MM(NR2,4)=MM(NR1,3)
MM(NR1,5)=2
MM(NR2,5)=2
ASINCD(NR1,3)=NR1
ASINCD(NR2,3)=NR2
LR=LR+1
TECLAP=TECLAP+1
KX=KX+1
GO TO 767
766 LR1=LR+1
LR=LR1
IF(LR.GT.ASIND) GO TO 788
GO TO 763
767 CONTINUE
788 IF(KX.NE.0) GO TO 789

```

```

C PRINT 122,CN,NS,K6,LR,ASIND,TECLAP,TPSA,NN
789 CONTINUE

```

```

C *****

```

```

C -----
C UPDATING AND STATISTICS
C -----

```

```

C *****

```

```

C .....
C WASTE CALCULATION
C .....

```

```

C .....

```

```

MA=LA

```

```

DO 810 I=1,TCLECT

```

```

KA=MM(IA,2)

```

```

IF(KA.LT.18) GO TO 820

```

```

KB=MM(IA,5)

```

```

IF(KB.GE.0) GO TO 805

```

```

CDATE=CDATE+1

```

```

UNASAD=UNASAD-1

```

```

IF(UNASAD.LT.0) UNASAD=0

```

```

TAGW=TAGW+1

```

```

MM(IA,5)=0

```

```

805 LA=LA+1

```

```

810 CONTINUE

```

```

820 CONTINUE

```

```

IF(TCLECT.GT.900) GO TO 599

```

```

C .....

```

```

C AGE UPDATING

```

```

C .....

```

```

DO 835 I=1,TCLECT

```

```

835 MM(I,2)=MM(I,2)+1

```

```

C .....

```

```

C STATISTICS PRINTING

```

```

C .....

```

```

LSP=LSP+UNASAD

```

```

AVINVP=LSP/EN
C PRINT 110,EN,COLECT,TCLCT,TNP,HRR,TED,TBSA,ASIND,TUNCAL,TBDAP,TS
C 1CRTG,TCALL,TCNLSF,CDATE,TUNCGW,TONLGH,TAGW,LX,NILW,UNASND
  CN=CN+1
  IF(CN.LE.30) GO TO 250
C PRINT 110,(DEMAND(I),I=1,30)
C PRINT 110,(INTAKE(I),I=1,30)
C PRINT 110,(NUCALD(I),I=1,30)
  AWASTE=CCATE
  AVBERP=TBD/TNP
  SORTP=FLCAT(TSCRIG)/FLCAT(TED)*100.
  WASTRD=AWASTE/FLCAT(TED)*100.
  WASTPC=AWASTE/FLCAT(TCLCT)*100.
  CALLP=FLCAT(TCALL)/FLCAT(TBSA)*100.
  UNCALP=FLCAT(TCNLSE)/FLCAT(TCALL)*100.
  UNRESP=FLCAT(TUNCAL)/FLCAT(TBSA)*100.
  UEFFIN=(FLCAT(TBSA)-FLCAT(ASIND))/FLCAT(TBSA)*100.
  PRINT 115,SIMNG,AVBERP,SORTP,WASTRD,WASTPC,CALLP,UNCALP,UNRESP,AV
1 INV,AWASTE,UEFFIN
  SIMNG=SIMNG+1.
  NEDDCM=NEDDCM-1
  IF(NEDDCM.GE.3) GO TO 124
  NFDCMS=NFDCMS+1
  IXX=IXX+1
  IF(NFDCMS.EQ.2)PRINT 109
  IF(NFDCMS.EQ.2) GO TO 123

```

```

999 STOP
END

```

```

C *****
C *****

```

```

$1BFTC RNDYX
FUNCTION RNDYX(XX)
INTEGER A,XX
DATA A/186277/
XX=A*XX
AY=XX
RNDYX=AY/34359738638.
RETURN
END

```

```

$1BFTC RNDYY
FUNCTION RNDYY(YY)
INTEGER B,YY
DATA B/186285/
YY=B*YY
BY=YY
RNDYY=BY/34359738638.
RETURN
END

```

```

$1BFTC RNDYV
FUNCTION RNDYV(VV)
INTEGER C,VV
DATA C/186293/
VV=C*VV
CY=VV
RNDYV=CY/34359738638.
RETURN

```

```

END
$IBFTC RNDYW
FUNCTION RNDYW(WW)
INTEGER C,WW
DATA C/186301/
WW=C*WW
DY=WW
RNDYW=DY/34359738638.
RETURN
END

```

```

$IBFTC RNDYZ
FUNCTION RNDYZ(ZZ)
INTEGER E,ZZ
DATA E/186309/
ZZ=E*ZZ
EY=ZZ
RNDYZ=EY/34359738638.
RETURN
END

```

```

$IBFTC INRAND
SUBROUTINE INRAND(NNN)
INTEGER AX,AY,AV,AW,AZ
COMMON /A/ AX,AY,AV,AW,AZ
IF(NNN.EQ.1) GO TO 50
GO TO 60
50 AX=11750920161
AY=27594084227
AV=10796931217
AW=17669802561
AZ=560227513
60 RN1=RNDYX(AX)
60 RN1=RNDYX(AX)
RN2=RNDYY(AY)
RN3=RNDYV(AV)
RN4=RNDYW(AW)
RN5=RNDYZ(AZ)
NNN=NNN+1
RETURN
END

```

SENTRY

\$JCB MEG371, TIMECC8, PAGE\$C10, NAME SPEKFOR 611403

APPENDIX.011

CM SAIRAM

EVALUATION OF STRATEGIES FOR THE MANAGEMENT OF REGIONAL BLOOD CENTRE
COMPUTER PACKAGE WITH : DAY RESERVATION HOLDING PERIOD

INTEGER CREM(60)
DIMENSION NUCALC(60)
INTEGER UNASNC, ASINC, CDATE, TUNCGW, TCNLCW, TAGW
INTEGER INTAKE(60), DEMAND(60)
INTEGER TCLECT
INTEGER RAEN(60), RDCMEN(60)

INTEGER CN, CPA, CEN, FPA, PBN, FBA, ABN, CCECT, RM1
INTEGER TESA, TPSA, TST, TWASTE
INTEGER TEC, TAP, TSTORTG, TCALL, TUNCAL, TCNUSE, TBDAF
INTEGER PRECUR(21), IST(21)
INTEGER NM(900, 5), ASINED(700, 3), DM(50, 5)
INTEGER CBNA(60), CBNB(60), CBNC(60), CBN
INTEGER AX, AY, AV, AW, AZ
COMMON /A/AX, AY, AV, AW, AZ

89 FORMAT(1H0, *NO DOUBLE CROSS MATCH*, 10I8)

92 FORMAT(1H0, 21I6)

93 FORMAT(15X, 10I6)

94 FORMAT(1H0, * DEMAND DAY NO *, 16, 4X, *CPN*, 8X, *CBN*, 8X, *PPN*, 8X, *
1PBN*, 6X, *STATUS*)

95 FORMAT(1H0, *DEMAND LIST OF THE DAY *, / (22X, 5I10))

96 FORMAT(1H0, *ASINED DAY NO *, 16, 14X, *PPN*, 7X, *PBN1*, 7X, *PBN2*)

97 FORMAT(1H0, * ASINED LIST OF THE DAY *, / (30X, 3I10))

98 FORMAT(1H0, 10I8)

100 FORMAT(1H0, 10I10)

101 FORMAT(1H0, * MATCH MATRIX OF THE DAY *, * PBN*, 7X, *AGE*, 6X, *PPPN*
1, 6X, *SNFN*, 5X, *CN STATUS*, / (22X, 5I10))

105 FORMAT(5X, * -----*, 10I6)

108 FORMAT(1H1, 14X, *RESULTS WITH SINGLE CROSS MATCH, 1 DAY HOLD*, //)

109 FORMAT(1H1, 14X, *RESULTS WITH DOUBLE CROSS MATCH, 1 DAY HOLD*, //)

110 FORMAT(5X, 15I8)

115 FORMAT(5X, 20I6)

120 FORMAT(1H0, 14X, *F6.2, 2F7.0, F6.2)

122 FORMAT(15X, *NO DOUBLE CROSS MATCH CN DAY NO ...*, 8I4)

125 FORMAT(5X, 30I4)

IXX=0

PRINT 108

NFDCMS=1

123 CONTINUE

SIMNC=13.

SIMNC=1.

ND=14

124 CONTINUE

NN=1

CALL INRANC(NNN)


```

10 DC 25 I=1,21
   PRCCUR(I)=0
25 IST(I)=0
   DC 25 I=1,50
   CM(I,1)=-1
   DM(I,2)=-1
   EM(I,3)=-1
   FM(I,4)=-1
   GM(I,5)=-1
35 CONTINUE
   DC 45 I=1,60
   DREN(I)=-1
   NLCALD(I)=-1
   IF(SIMNCCT.24.) INTAKE(I)=-1
   DEMAND(I)=-1
   CENA(I)=-1
   CBNE(I)=-1
   CBNC(I)=-1
   RABN(I)=-1
45 RECMEN(I)=-1
   DC 65 I=1,700
   ASINED(I,1)=-1
   ASINED(I,2)=-1
65 ASINED(I,3)=-1
   DC 75 I=1,900
   MM(I,1)=-1
   MM(I,2)=-1
   MM(I,3)=-1
   MM(I,4)=-1
75 MM(I,5)=-1
   TEC=0
   TAP=0
   TSORTG=0
   TCALL=0
   TUNCAL=0
   TCNUSE=0
   TBDAP=0
76 TCLECT=0
   ASINC=0
   GCATE=0
   TONCEW=0
   TCNUGW=0
   TAGW=0
   KZ=0
   UNASND=0
   TESA=0
   NN=C
   LR=0
   LC=0
   TST=0
   LA=1
   PPN=1
   AEN=1
   INCCA=0
   LX=0
   DN=1

```

```

      N4=C
      LSP=C
      N1LW=0
      INC=EN-(DN/3)*3
1  IF(INCON.EQ.(-1)) GO TO 50
C *****
C  INITIAL STOCKING
C *****
      DO 5 I=18,21
5  IST(I)=0
      DO 30 L=1,17
      K=18-L
      IST(K)=RNDYX(AX)*44
      IN=IST(K)
      IF(IN.EQ.0) GO TO 3
      N3=N4+1
15 N4=N4+IN
      DO 20 I=N3,N4
      PEN=I
      MM(PEN,1)=I
      MM(PEN,2)=K
      MM(PEN,3)=0
20 CONTINUE
30 CONTINUE
      INCON=-1
      TST=TST+N4
      UNASND=UNASND+N4
      K4=N4
C *****
C  PROCCUREMENT
C *****
      IF(IXX.NE.0) GO TO 34
      IF(SIMNC.NE.1) GO TO 34
      READ 33,(INTAKE(I),I=1,30)
33 FORMAT(20F4)
34 CONTINUE
50 CONTINUE
      LF=DN/3
      INC=EN-3*LF
      IF(INC.EQ.0) INC=3
      COLLECT=RNDYX(AX)*81
      IF(IXX.NE.0) GO TO 37
      IF(SIMNC.EQ.12) INTAKE(DN)=COLLECT
37 CONTINUE
      IF(SIMNC.LE.24) COLLECT=INTAKE(DN)
      IF(COLLECT.EQ.0) COLLECT=1
      PROCLR(1)=COLLECT
      INTAKE(DN)=COLLECT
36 K3=K4+1
      K4=K4+COLLECT
      DO 40 I=K3,K4
      PEN=I
      MM(I,1)=1
      MM(I,2)=1
      MM(I,3)=0
40 CONTINUE

```

```

41 TCOLLECT=K4
TST=TST+COLLECT
UNASND=UNASND+COLLECT
JX=6
JY=6

```

```

C *****
C RETURN OF CALLED ELT UNUSED BOTTLES
C -----

```

```

IF(IN.LE.4) GO TO 710
BR=NLCALC(IN-3)
NGBR=RNBYV(AV)*BR
LX=NGBR
LY=0
IF(LX.EQ.0) GO TO 690
IF(IAC.EQ.1) GO TO 620
IF(IND.EQ.2) GO TO 650
LY=CENC(3)-5
IF(LY.LE.0) GO TO 690
IF(LX.GT.LY) LX=LY
DC 620 JU=1,LX
REN=CENC(JU+5)
MM(REN,3)=0
MM(REN,4)=0
IF(MM(REN,2).LE.17) GO TO 615
MM(REN,5)=0
TCNUGW=TCNUGW+1
CCATE=CCATE+1
GO TO 620
615 UNASND=UNASND+1
RABN(JX)=REN
JX=JX+1
MM(REN,5)=-1
620 CONTINUE
GO TO 700
630 LY=CBNA(3)-5
IF(LY.LE.0) GO TO 690
IF(LX.GT.LY) LX=LY
DC 640 JV=1,LX
REN=CBNA(JV+5)
MM(REN,3)=0
MM(REN,4)=0
IF(MM(REN,2).LE.17) GO TO 635
MM(REN,5)=0
TCNUGW=TCNUGW+1
CCATE=CCATE+1
GO TO 640
635 UNASND=UNASND+1
RABN(JX)=REN
JX=JX+1
MM(REN,5)=-1
640 CONTINUE
GO TO 700
650 LY=CBNB(3)-5
IF(LY.LE.0) GO TO 690
IF(LX.GT.LY) LX=LY
DC 660 JW=1,LX

```

```

RBN=CEN(JX+1)
  MN(RBN,3)=0
  MN(RBN,4)=0
  IF(MN(RBN,2).LE.17) GO TO 655
  MN(RBN,5)=0
  TCNLCW=TCNLCW+1
  CDATE=CDATE+1
  GO TO 660
655 UNASND=UNASND+1
  RAEN(JX)=REN
  JX=JX+1
  MN(RBN,5)=-1
660 CONTINUE
  GO TO 710
690 CONTINUE
C PRINT 495,EN,INC
695 FORMAT(1H,4NC RETURN OF CALLED BOTTLES ON DAY NO--*,1016)
  IF(LY.LE.0) GO TO 705
700 TCNLCSE=TCNLCSE+LX
705 RAEN(3)=JX-1
  RABN(1)=CN
  RAEN(4)=3
  LKR=RABN(3)
710 CONTINUE
  IF(EN.EQ.1) GO TO 290
  LK=5
  LC=0
  LKK=IZ+5
  DO 280 I=6,IZ
    AXX=PNXYZ(AZ)
    BXX=PNZYW(AW)
    IF(AXX.LT.BXX) GO TO 278
    CBN=CRBN(I)
    LC=LC+1
    IF(I.EQ.IZ) LKK=LC+5
    LHH=MN(CBN,5)
    IF(LHH.EQ.1) GO TO 250
    IF(LHH.NE.2) GO TO 279
    KAS=ASINED(CBN,3)
    IF(KAS.LT.1) GO TO 250
    ASINED(CBN,3)=0
    ASINED(KAS,3)=0
    MN(CBN,4)=-2
    MN(KAS,4)=-2
    IF(CBN.LT.KAS) GO TO 230
    MN(CBN,5)=1
    CEN=KAS
    GO TO 250
230 MN(KAS,5)=1
250 MN(CBN,5)=2
255 LK=LK+1
  IF(INC.EQ.1) GO TO 360
  IF(INC.EQ.2) GO TO 270
  CENC(LK)=CEN
  IF(LK.LT.LKK) GO TO 280
257 CENC(1)=CN

```

```

      CBNC(2)=INC
      CBNC(3)=LKK
      GO TO 90
260  CBNA(LK)=CBN
      IF(LK.LT.LKK) GO TO 280
267  CBNA(1)=CN
      CBNA(2)=INC
      CBNA(3)=LKK
      GO TO 90
270  CBNB(LK)=CBN
      IF(LK.LT.LKK) GO TO 280
277  CBNB(1)=CN
      CBNE(2)=INC
      CBNE(3)=LKK
      IF(1.EQ.IZ) GO TO 90
278  IF(1.LT.IZ) GO TO 290
      IF(LC.EQ.0) GO TO 260
      LKK=LC+5
      GO TO (267,277,287),INC
279  LC=LC-1
280  CONTINUE
290  CONTINUE
C     PRINT 295,CN
295  FORMAT(1H0,* NO BOTTLE CALLED CN DAY NUMBER-----*,10I6)
300  FORMAT(5X,20I4,/)
90   CONTINUE
      TCALL=TCALL+LC
      NUCAL(CN)=LC
C     *****
C     CANCELTION OF RESERVATION
C     -----
      IF(CN.EQ.1)GO TO 600
      DO 590 I=6,12
      LP=DRBN(I)
      LS=MM(LP,5)
      IF(LS.EQ.0) GO TO 590
      IF(LS.EQ.3) GO TO 590
      IF(MN(LP,2).LE.17) GO TO 520
      IF(LS.NE.2) GO TO 515
      LPM=ASINED(LP,2)
      IF(LPM.LF.0) GO TO 515
      MM(LPM,5)=1
      ASINED(LPM,3)=-2
      ASINED(LP,3)=-2
515  CONTINUE
      MN(LP,5)=0
      TUNCGW=TUNCGW+1
      CCATE=CCATE+1
      GO TO 590
520  IF(LS.NE.1) GO TO 540
      RABN(JX)=LP
      MN(LP,3)=0
      MN(LP,5)=-2
      GO TO 580
540  IF(LS.NE.2) GO TO 590
      LPA=ASINED(LP,3)

```

IF(NM(LPA,5),LF,0) GO TO 550

NM(LF,3)=NM(LF,4)

NM(LF,4)=-2

NM(LF,5)=3

RCCMEN(JY)=LF

JY=JY+1

GO TO 560

550 LPA=LF

560 CONTINUE

RABN(JX)=LPA

NM(LPA,3)=0

NM(LPA,4)=-2

NM(LPA,5)=-2

ASINED(LPA,2)=-2

ASINED(LPA,3)=-2

ASINED(LP,2)=LPA

ASINED(LP,3)=-2

580 TUNCAL=TUNCAL+1

UNASND=UNASND+1

JX=JX+1

590 CONTINUE

RABN(1)=DN

RABN(4)=5

RABN(7)=JX-1

LKR=RABN(3)

RCCMEN(1)=DN

RCCMEN(4)=7

RCCMEN(3)=JY-1

LKS=RCCMEN(3)

600 CONTINUE

IF(DA.NE.1) GO TO 56

C *****

C DEMAND

C *****

55 N2=0

K2=0

56 CONTINUE

NCPR=1+RNDYX(AX)*13.

TNP=1NP+NCPR

NRR=0

N1=N2+1

57 N2=N2+NCPR

NRC=0

KZ=5

IZ=6

DO 80 J=N1,N2

NRC=NRC+1

CPA=NRC

PPA=J

RN=1+RNDYY(AY)*4.

C *****

C DM ENTRY

C *****

NERBP=RN

K1=K2+1

60 K2=K2+NERBP

```

    GO TO KK=K1,K2
64  NRR=NRR+1
    DEN=KK
    CM(NRR,1)=NRC
    CM(NRR,2)=NRR
    TED=TED+1
    IF(LNASND.GT.0) GO TO 66
C   *****
C   SHORTAGE
C   *****
    CM(NRR,3)=0
    CM(NRR,4)=0
    CM(NRR,5)=0
    TSCRTG=TSCRTG+1
    GO TO 70
C   *****
C   ASSIGNMENT ENTRY
C   *****
66  INDEX=1
    IF(CN.EG.1) GO TO 168
    KRP=0
    KM=RAEN(2)
    IF(KM.LT.6) GO TO 167
    NA=KZ+1
    IF(NA.GT.KM) GO TO 167
    IF(KZ.GT.KM) GO TO 167
    DO 67 KR=NA,KM
    KA=RABN(KR)
    KZ=KZ+1
    IF(M(KN,2).GT.17) GO TO 67
    ABN=KN
    INDEX=0
    KRP=KR
    ASINED(ABN,1)=J
    ASINED(ABN,2)=ABN
    GO TO 169
67  CCNTINUE
167  ABN=ASINC+1
168  ASINED(CBN,2)=ABN
    ASINED(CBN,1)=J
169  UNASND=UNASND-1
    CBN(IZ)=ABN
    IF(UNASND.LT.0) UNASND=0
    ASINED(CBN,2)=ABN
    CM(NRR,3)=J
    CM(NRR,4)=ABN
    CM(NRR,5)=1
    MM(ABN,5)=1
    MM(ABN,3)=J
    TESA=TESA+1
    IZ=IZ+1
    TPA=J
69  CCNTINUE
    IF(INDEX.EG.0) GO TO 70
    ABN=ABN+1
    ASINC=ASINC+1

```

```

70 CONTINUE
80 CONTINUE
  DBN(1)=CN
  IZ=IZ-1
  DBN(3)=IZ
  DBN(2)=6
  DEMANC(CN)=NFR
  IF(CN.EQ.1) GO TO 124
  IF(KN.LE.KRP) GO TO 134
  LW=KN-KRP
  NTLW=NTLW+LW
  UNASND=UNASND-LW
  IF(UNASND.LT.0) UNASND=0
134 CONTINUE
  IF(NFDCMS.EQ.1) GO TO 789
C *****
C DOUBLE CROSS MATCHING
C *****
721 N5=TECAP+1
  KX=0
  N6=TECAP+(ASINC-TECAP)/2
722 LR=N6
  IF(N6.LE.N5) GO TO 788
  KLL=6
  KP=RDCMEN(3)
  DO 767 NN=N5,N6
  NR1=NN
  IF(CN.LE.1) GO TO 745
  IF(KP.LT.6) GO TO 745
  IF(KLL.GT.KP) GO TO 745
  NR1=RDCMBN(KLL)
  KLL=KLL+1
745 IF(NN(NR1,5).EQ.1) GO TO 753
  NR1=NR1+1
  IF(NR1.GT.ASINC) GO TO 788
  GO TO 745
753 NR=NN(NR1,2)
  JS=NN(NR1,5)
763 NR3=NN(LR,2)
  JR=NN(LR,5)
  JC=NR-NR3
  IF(JC.LT.NC) GO TO 766
  IF(JS.NE.1) GO TO 767
  IF(JR.NE.1) GO TO 766
764 NP1=NR3
  KT=LR-1
  NP2=NN(KT,2)
  IF(NP1.NE.NP2) GO TO 765
  NP3=NN(KT,5)
  IF(NP3.EQ.2) GO TO 765
  LR=LR-1
  GO TO 764
765 NR2=LR
  NN(NR1,4)=NN(NR2,3)
  NN(NR2,4)=NN(NR1,3)
  NN(NR1,5)=2

```



```

MM(NR2,5)=2
ASINED(NR1,3)=NR2
ASINED(NR2,3)=NR1
LR=LR+1
TECAP=TECAP+1
KX=KX+1
GO TO 767
766 LR1=LR+1
    LR=LR1
    IF(LR.GT.ASINC) GO TO 788
    GO TO 763
767 CONTINUE
788 IF(KX.NE.0) GO TO 789
    NN=1000
789 CONTINUE

```

TOTAL WASTE CALCULATION

```

IF(TCLECT.GT.900) GO TO 1000
DC 410 1A=1, TCLECT
KA=MM(1A,2)
IF(KA.LT.18) GO TO 500
IF(MM(1A,5).GE.0) GO TO 405
CCATE=CCATE+1
UNASND=UNASND+1
IF(UNASND.LT.0) UNASND=0
TAGW=TAGW+1
MM(1A,5)=0
405 LA=LA+1
410 CONTINUE
500 CONTINUE
DC 91 IT=1, TCLECT
91 MM(IT,2)=MM(IT,2)+1

```

PRINTING RESULTS

```

LSP=LSP+UNASND
AVINVP=LSP/DN
PRINT 115,DN,CCLECT,TCLECT,TNP,NRR,TEC,TBSA,ASINC,TUNCAL,TECAP,TS
10RTG,TCALL,TCNUSE,CCATE,TUNCW,TCNUGW,TAGW,LX,NTLN,UNASND
CA=CA+1
IF(CN.LE.20) GO TO 50
AWASTE=CCATE
AVBDPP=TEC/TAP
SCRTF=FLCAT(TSCRTG)/FLOAT(TEC)*100
WASTPD=AWASTE/FLCAT(TEC)*100
WASTPC=AWASTE/FLCAT(TCLECT)*100
CALLP=FLCAT(TCALL)/FLCAT(TBSA)*100
UNCALP=FLCAT(TCNUSE)/FLCAT(TCALL)*100
UNRESP=FLCAT(TUNCAL)/FLCAT(TBSA)*100
LEFFIN=(FLCAT(TBSA)-FLCAT(ASINC))/FLCAT(TBSA)*100
PRINT 120,SIMND,AVBDPP,SCRTF,WASTPD,WASTPC,CALLP,UNCALP,UNRESP,AV
11INVP,AWASTE,LEFFIN
SIMNC=SIMNC+1
ND=ND-1
IF(ND.GE.3) GO TO 124

```

```

NFD CMS=NFD CMS+1
IXX=IXX+1
IF(NFD CMS.EQ.2)PRINT 109
IF(NFD CMS.EQ.2) GO TO 123
1000 STOP
END
$IBFTC RNDYX
FUNCTION RNDYX(XX)
INTEGER A,XX
DATA A/186277/
XX=B*XX
AY=XX
RNDYX=AY/34359738638.
RETURN
END
$IBFTC RNDYY
FUNCTION RNDYY(YY)
INTEGER B,YY
DATA B/186285/
YY=B*YY
BY=YY
RNDYY=BY/34359738638.
RETURN
END
$IBFTC RNDYV
FUNCTION RNDYV(VV)
INTEGER C,VV
DATA C/186293/
VV=C*VV
CY=VV
RNDYV=CY/34359738638.
RETURN
END
$IBFTC RNDYW
FUNCTION RNDYW(WW)
INTEGER D,WW
DATA D/186301/
WW=D*WW
DY=WW
RNDYW=DY/34359738638.
RETURN
END
$IBFTC RNDYZ
FUNCTION RNDYZ(ZZ)
INTEGER E,ZZ
DATA E/186309/
ZZ=E*ZZ
EY=ZZ
RNDYZ=EY/34359738638.
RETURN
END
$IBFTC INRAND
SUBROUTINE INRAND(NNN)
INTEGER AX,IY,AV,AW,AZ
COMMON /A/AX,AY,AV,AW,AZ
IF(NNN.EQ.1) GO TO 50

```

GC TC 60

50 AX=11750920161

AY=27594084227

AV=10796931217

AW=17669802561

AZ=560227513

60 RN1=RNDYX(AX)

RN2=RNDYY(AY)

RN3=RNDYV(AV)

RN4=RNDYW(AW)

RN5=RNDYZ(AZ)

NN=NN+1

RETURN

END

SENT BY